MAJOR WORK

HSC Industrial Technology - Electronics

BOS ID: 27051731

Table of Contents

Design, Management and Communication

HSC Industrial Technology - Electronics

BOS ID: 27051731

Statement of Intent

I believe there is plenty of future real world potential in robotics and automation in **all** industries.

Mobile robots can be remotely operated or fully autonomous, they can be commanded remotely from a computer, phone or tablet device, allowing: the unmanned transportation of goods, surveillance or environment sensing/monitoring,

I can see robotics used in all different applications, for example:

- Logistics (Unmanned Autonomous transportation of heavy packages and goods)
- Medical Industry (Autonomous transportation of food and medical equipment)
- Retail Industry (Autonomous transportation of goods within a store, food delivery in restaurants)
- Tourism Industry (Autonomous tour guides)
- Hazardous Environments/Situations (Bomb disposal or fire-fighting robots)

A single robot platform could be designed to be **modular** and **adaptable** to suit these applications with minimal change of the hardware, with only changes to software required.

The aim of this project is to develop a **modular** outdoor robot platform which could be **customised** to fit a variety of the given applications, suiting different needs and/or industries; by fabricating attachments to perform certain tasks, (e.g. a wheelbarrow bucket attachment, for carrying landscaping supplies)

A prototype base of the **modular** robot could be then be developed and redesigned for production manufacture.

I plan to build a robot for several reasons, including:

- Out of personal interest
- To gain experience with building robotics, I plan to study Mechatronic Engineering and work in the field of robotics.
- Investigating the practical advantages and disadvantages and of mobile robotics in industry
- Being able to later adapt the robot to suit my needs if necessary (for example: to transport heavy goods, instead of having to carry them)
- Being able to use the robot for other (university etc.) projects and to engage in robotics research in future

As a base level, I plan to have it teleoperated by an operator through a controller, some ideas possible extensions to the project, of **which I may consider only if time permissible** include:

- Remote teleoperation relaying live video, map position and sensor feedback from the robot to a remote operator located on the local network or the Internet.
- Use voice recognition commands from to stop or manoeuvre the robot if it is stuck or at risk of damaging or hurting something or someone.
- Autonomous navigation of the environment, using a combination of:
    - dead-reckoning techniques (use on-board sensors to estimate where the robot is and what is around it)
    - absolute references (external information sent to the robot about its location, e.g.: GPS or stationary markers)
- A hot swap battery charging circuit for convenience, allowing simultaneous use and charging of batteries
- Video Documentation and posters to help demonstrate the project and convey the intentions and evaluate the project, alongside the folio.

I aim to complete this project and folio at a high standard, ensuring everything is: **modular, practical, adaptable, tidy, maintainable and repeatable**.

Research of components, processes, technologies and resources

I did all my research with a top down approach.

I start by first looking into a background of mobile robots: practical uses, designs and features, availability on the market, similar projects.

I then started investigating mechanical constraints, i.e. looking into sizing, motor types, battery configurations and physical construction. I then focused my research on electronics, taking the constraints set by the mechanical design into account.

Materials

Aluminium

Aluminium is a lightweight non-corrosive metal perfect for use on a robot chassis. It can be finished painted, anodised or polished. Aluminium can be easily recycled from metal scrap yards.

Steel

Steel is a cheap, strong and accessible metal, although corrosive and relatively heavy. It is commonly available in box section, angle section or sheets. Steel can be easily recycled from metal scrap yards.

Acrylic

Acrylic sheets are flat sheets of material that come in multiple styles (glossy, reflective, transparent or opaque) and a large range of colours.

They are reasonably brittle but still fairly strong, especially when reinforced.

They can be cut by hand, or very precisely and fast with a laser cutter. 5mm sheets will slide directly into the groove in the v-slot.

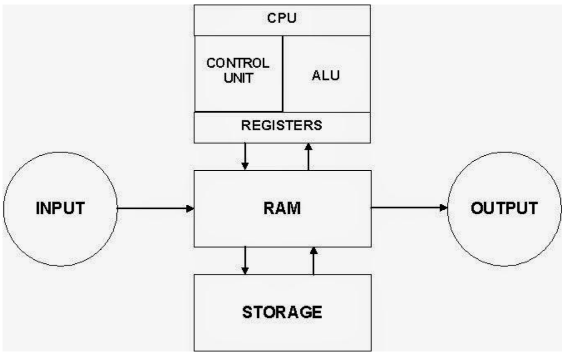
Technologies

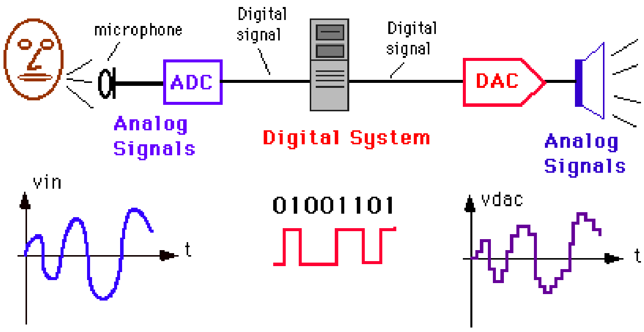
Computer Data acquisition and control

In order for a computer to process electrical signals from sensors or input devices, they have to be converted into digital signals if they aren't already.

The computer is then able perform a logical/arithmetical operation using software, and hence control an output device (actuator) e.g. a light or motor, through a driver circuit (e.g. using a relay, or power transistor) based on the state of the input signal(s).

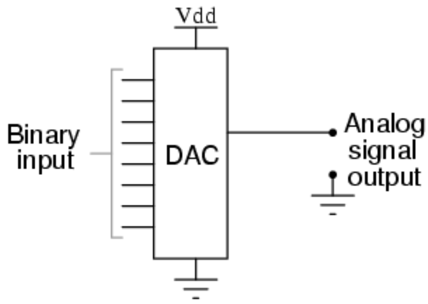
This is the basis of computer controlled robotics.





Digital to Analogue Converter (DAC)

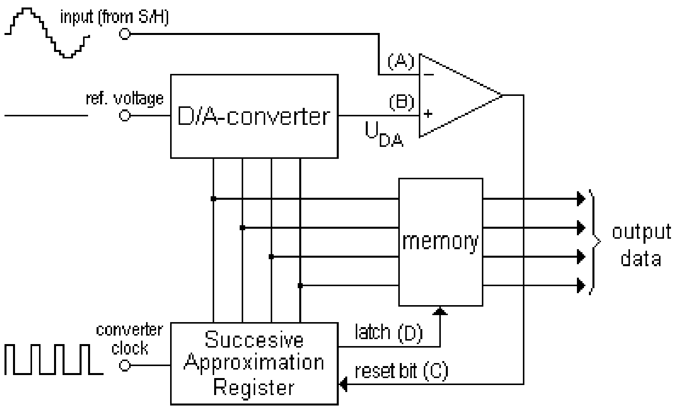
A digital to analogue converter convert's a digital signal in binary to an analogue voltage.



Analogue to Digital Converter (ADC)

An analogue to digital converter converts an analogue voltage to a digital signal in binary.

It determines the input voltage by iteratively comparing a ramping voltage output from a DAC with the analogue input voltage.



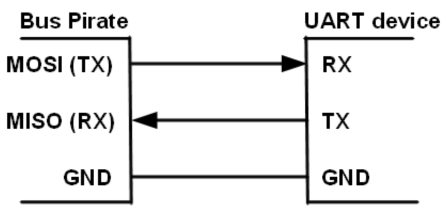
Digital Communication Protocols

Pulse Width Modulation (PWM)

PWM is a modulation technique used to encode a message onto a digital square carrier wave of fixed frequency, by simply adjusting the duty cycle of the signal.

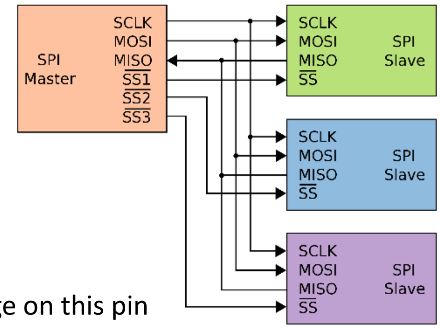
Asynchronous Serial

Asynchronous serial (UART, TTL, RS-232, RS-485, RS-422 are all variants using different logic levels) allows two electronic devices to communicate bidirectionally, without being synchronised by a common clock. One wire is used for communication in each direction, the data is encoded in binary.



Asynchronous serial is how computers and microcontrollers communicate to each other and various sensors e.g. (GPS).

Serial Peripheral interface (SPI)



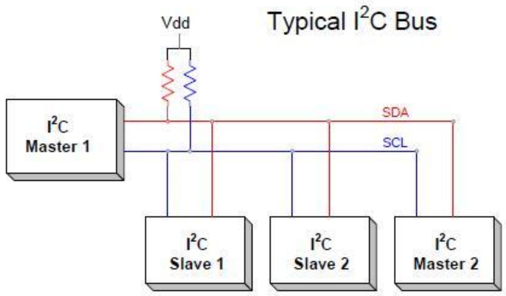
SPI allows the communication of multiple devices on a shared bus. Timing is controlled by the "Master", only one "Slave" device can communicate to the master at a given time, otherwise their messages would interfere with each other.

The data is encoded in binary.

Each slave has its own Slave Select Pin, which the "Master" controls, the voltage on this pin tells the "Slave" devices when they can transmit data without interrupting another message from another "Slave" device.

SPI is commonly used on a large number of integrated circuits and sensors, so that they communicate with each other.

Inter-Integrated Circuit (I2C)



I2C is a communications protocol that allows multiple "Slaves" to communicate with the "Master" using only two wires. Each slave is given an address so that the messages are delivered to the right "Slave devices"

I2C is commonly used for sensors such as temperature sensors, IMUs, pressure sensors.

An 8 Bit Microcontroller

An 8 bit microcontroller is small programmable IC, it contains a microprocessor, volatile and non-volatile memory and is capable of controlling general purpose inputs and outputs (GPIO), they usually contain several ADC and interrupt inputs, sometimes a DAC outputs, and they can easily digitally interface to: I2C, RS-232 and SPI busses.

They are generally available in both Through Hole and Surface Mount chip Package sizes.

A 32 Bit Microcontroller

Similar to an 8 bit microcontroller but generally more expensive with a faster more versatile processor, with more available resources. Generally only available in a Surface Mount Package size.

A Field Programmable Gate Array (FPGA)

An FPGA is a configurable IC with the ability to internally reroute the internal hardware logic blocks through software.

An FPGA is **much faster than a processor** because it is physically electronically hardwired internally by the system integrator to **perform a single task** like an electronic circuit, rather than iteratively process software line by line.

They are generally more expensive than a regular microcontroller, but still reasonably priced, the lower end portfolio of FPGA's start at around $30.

The disadvantage of an FPGA is that it is not a general purpose processor and can only perform a single task.

Batteries

Lead-Acid

Lead-Acid batteries are rechargeable batteries that store charge in sulphuric acid separated by lead sheet plates. The energy-to-weight and energy-to-volume densities are very low, although they are very cheap and accessible. The individual cells are 3V each.

Lithium Ion

Lithium Ion batteries are rechargeable batteries that have extremely high energy-to-volume and energy-to-mass density, they store charge in cells comprised of lithium ions which flow from a negative to a positive electrode when discharging, the reverse occurs when charging. The Cells are 3.7V optimal voltage. Although they can be easily damaged when over-discharged.

Nickel Metal Hydride

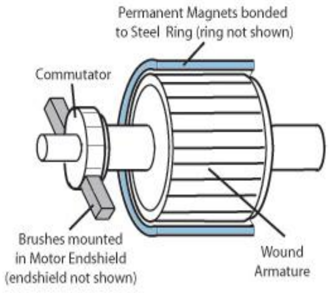
Nickel Metal Hydride batteries are rechargeable with high energy-to-volume and energy-to-mass density, they are much more versatile, unlike Lithium Ion they allow full cycle discharges and are more robust than lithium ion varieties.

Motors

Once I had researched the chassis configuration and the batteries, I investigated different types of Motor's to use on the drive-train of the robot.

There were four main types of motors I found available, including:

Brushed DC Motors



A brushed DC motor is the simplest form of electric motor, using a permanent magnet and an armature (coil of wires, electromagnet).

The armature is attached to the outside through electrical contacts called the commutator and brushes. The commutator changes the current direction every half rotation, reversing the magnetic field so that the electromagnet and permanent magnet always repel, resulting in continuous smooth rotation.

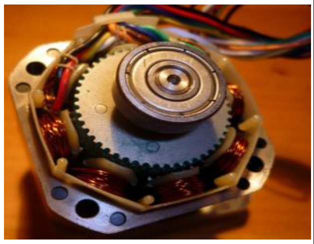
Brushless Motors

Brushless motors are much more efficient and powerful than DC motors.

The shaft is a permanent magnet, the coil windings are on the exterior.

The windings electrically change their polarity in a circular pattern based on the position of the shaft (detected using sensors), magnetically attracting the shaft, causing it to rotate.

Stepper Motors



Stepper motors are Brushless motors that utilise multiple toothed electromagnets around a central gear to drive the shaft a set number of steps.

Stepper Motors come in several standard sizes with standard mounting hole placements, the most common sizes include:

NEMA 17 Size

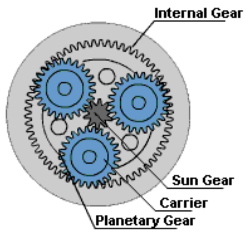
NEMA 23 Size

NEMA 23 Size

Gearbox

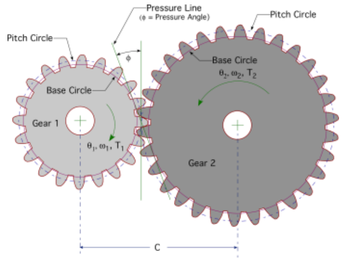
The output shaft on the any type of motor can also optionally be attached to a gearbox to increase the torque and reduce the angular velocity. These are the most common Gear configurations:

Planetary Gearbox



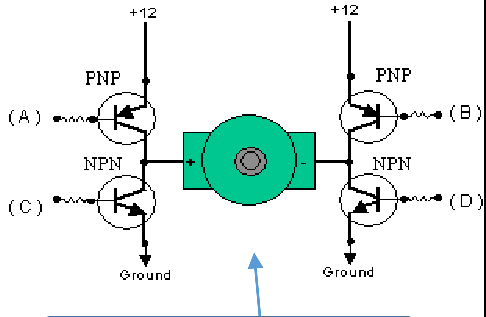
A planetary gearbox uses a stationary internal gear and three or more "planets" which rotate around the "sun" gear (which is attached to the input shaft from the motor) at the centre along with the carrier and output shaft. A planetary gearbox is approximately 97% efficient.

Spur Gearbox



A spur gearbox is an extremely simple design using two gears of different sizes to transfer kinetic energy through the teeth. A spur gearbox is 85% efficient

Motor drivers



H-Bridge driving DC Motor

I decided to use DC motors in my Design (full reasoning for this decision in Selection and Justification of Materials, Processes and Resources section below), for directional control an H-Bridge motor driver attached to either a Microcontroller or digital logic is required.

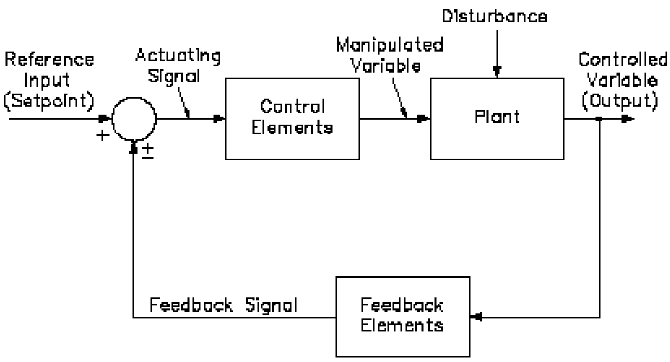
An H-Bridge is a simple circuit that uses a PNP transistor on the high side and a NPN transistor on the low side per channel, these transistors are usually MOSFETS, by activating the transistors on in different arrangements the direction of current through the motor coil can be manipulated.

Motor Feedback (Motor/Wheel Encoders)

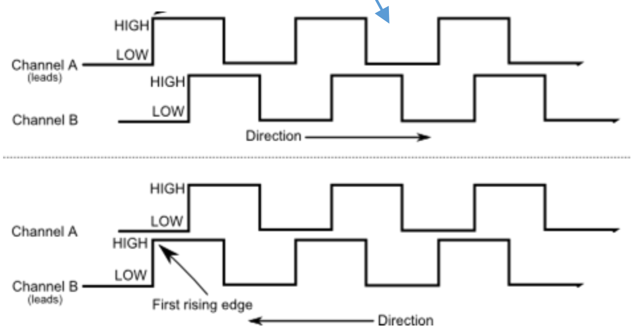
Incremental or Absolute Quadrature Encoders can optionally be attached to a shaft for position and velocity information can be inferred using logic.

Incremental Quadrature Encoders are the cheapest and most common encoders available, they generate two square waves 90 degrees out of phase, so that: position, direction and velocity can be infrared using logic.

Closed Loop Feedback Control

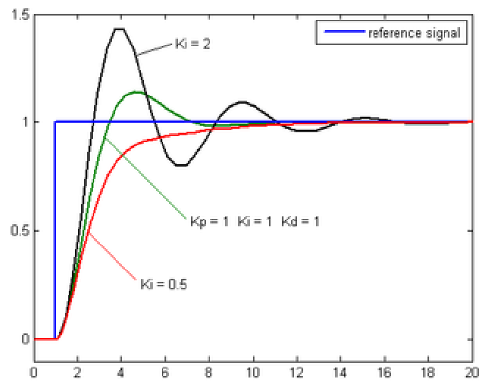


Quadrature Square Wave Signals from Motor Encoders



In a Closed loop Feedback control System, the output (Motor Voltage) has an effect on the input (Motor Speed). In the case of motor control, a position sensor (Motor Encoder) could be placed on the shaft to ensure the motor is spinning at the correct speed, if not; the voltage applied to the motor can be adjusted accordingly using a PID Controller.

PID Control



An example of a closed loop feedback controller is a PID controller.

A PID controller is a control loop feedback system generally used in industrial control. A PID controller ensures that the output (motor shaft speed in my case) is as close to the commanded input as possible, compensating for overshoot and undershoot, while remaining smooth and stable.

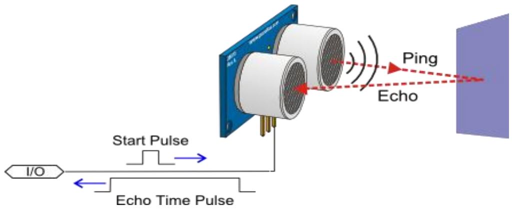
E.g. If the wheel is slipping and sensed spinning too fast; reduce power from the motor to slow it down. Or if the wheel is stuck on an object and spinning too slow; apply more power to the motor to speed it up.

Proximity Sensors

I Investigated sensors to detect obstacles, I found LIDAR (Light based), SONAR (Sound based) and RADAR (Radio based) sensors. 2D LIDAR would be the best option but the only economically feasible types I found were Ultrasonic Proximity Sensors or Infrared Proximity sensors.

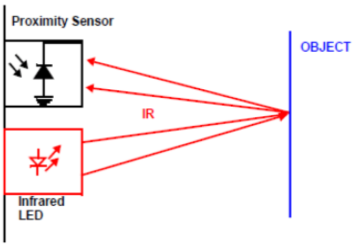
Ultrasonic Proximity Sensor

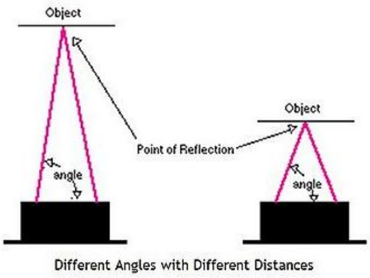
Ultrasonic proximity sensors measure the time taken for an ultrasonic sound to be reflected off an object, then calculating the distance to the object using the speed-distance-time relationship, knowing the speed of sound for a given temperature.



Infrared Proximity Sensor

The Infrared distance sensor reflects light off an object similar to the ultrasonic sensor, but unlike the ultrasonic, it calculates the distance by measuring the angle of subtended by the reflected light which is proportional to the distance away from the object, not the time taken for the pulse to reflect into the sensor.





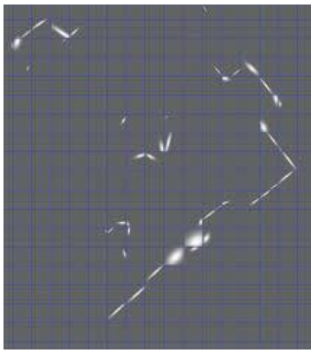
LIDAR 2D Proximity Sensor

2D LIDAR is a two dimensional proximity sensor giving a full 2D cross sectional “slice” image of the surrounding environment.

It works by physically rotating a laser and photo-detector around, iteratively measuring the angle subtended by the reflection of the light.

Note: the class 1 laser is safe for human eye exposure for all conditions of normal use.

The measurement is repeated at different angular positions several thousand times per second, these 1D images are amalgamated giving a 2D map of the environment.



A visual representation of a room as seen from a single LIDAR scan. (The walls of the room and obstacles inside the can be seen)

A map generated of a room using the SLAM technique, from combining multiple LIDAR Scans

SLAM

Simultaneous localisation and mapping (SLAM) is the technique of constructing a map of the environment around the robot while estimating the position of the robot within it.

SLAM is usually done using a LIDAR sensor. It combines consecutive LIDAR scans as the robot moves to different positions to generate a map, it can then estimate the position of the robot within the map.

RGB-Depth Camera

An RGBD camera provides a colour image, overlayed with depth information for each pixel (the distance measuremnets to the objects within each pixel)

RGBD Cameras typically project an infrared dot pattern, and measure the position of the reflections of the dots using an infrared camera, and hence calculate the distance to the objects reflecting.

A colour Image is then overlayed over the depth Image on a computer.

Environmental Sensors

Environmental Sensors can be used to measure the weather and conditions surrounding the robot, this is useful data that can be sent back to a remote operator, informing the operator of any adverse conditions.

Temperature

Temperature sensors measure the temperature of the case of the component.

I plan to use multiple temperature sensors on-board of the robot, to monitor the temperature state of the batteries, motors and computer, as well as the outdoor temperature surrounding the robot.

Barometric Pressure

Barometric pressure sensors measure the atmospheric air pressure. The atmospheric pressure fluctuates regularly due to air temperature, storm fronts and moisture.

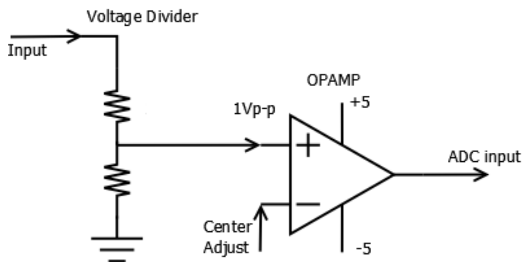
If the current sea level air pressure is known (can be provided to the robot by online weather services), the current altitude of the robot can be calculated with a resolution of about ±5cm.

Light Sensor

A light sensor changes its resistance based on the amount of light exposed to it, a light sensor could be used to automatically turn on headlights and auxiliary lighting in dark conditions.

Electricity Sensors

Voltage Sensors

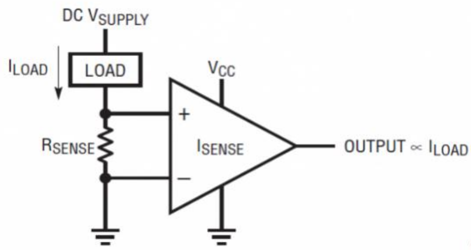


Digital voltage sensors can be made using a voltage divider (to proportionally scale down a high voltage, to a lower voltage) attached to an ADC input.

This allows a microcontroller or simillar device to measure high voltages.

I plan to make a voltage sensor to measure the voltage rails of the robot, most importantly the battery voltage. The operator will be alerted of a battery undervoltage condition (low battery) and the robot will be automaticly safely shut down, preventing damage to the battery or the robot itself.

Current Sensors



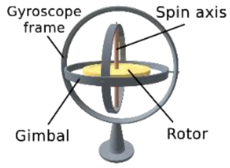
Current sensors are composed of a resistor with an extremely low resistance (< 0.1Ω) in series with the load (also known as a shunt/sense resistor configuration), <u>the voltage drop across the resistor is proportional to the current passing through it</u>.

This difference in voltage is amplified using an operational amplifier, then the output can be fed into an ADC and read by a microcontroller.

I plan to use current sensors on the motors in a feedback loop on the robot to safely control the amount of power applied to each motor and ensure the motors are not damaged due to an overcurrent condition.

Inertial Measurement Unit (IMU)

An IMU determine orientation, acceleration and rotational velocity by fusing a combination of data from accelerometers, gyroscopes and magnetometers. IMU's generally use an I2C, SPI or UART to interface with a computer.

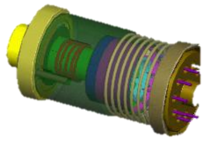


Gyroscope

A gyroscope is an instrument that measures the angular velocity of rotational motion.

Accelerometer

Accelerometers are instruments that measure acceleration (the rate of change of velocity).

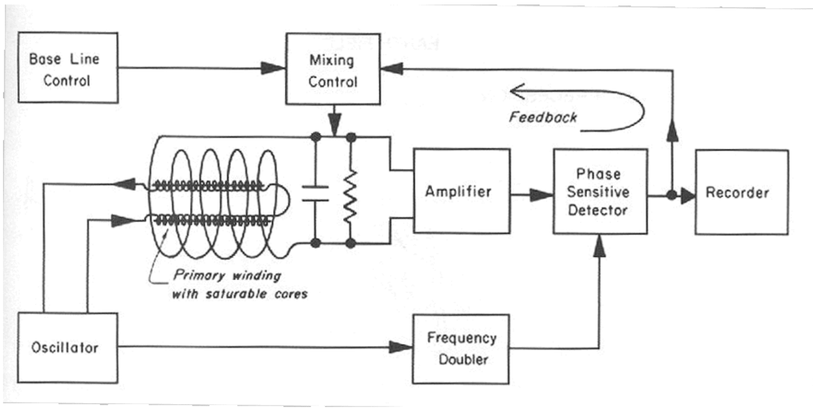


An accelerometer can be used to determine the roll and pitch (incline or tilt) of the robot, based on the acceleration due to earth's gravitational field.

Magnetometer

A magnetometer is used to measure the strength of a magnetic field in a given direction. The direction of the magnetic field can be determined using a combination of magnetometers placed on an XYZ axis.

A magnetometer can be used to determine the magnetic "compass heading" of the robot.



Global Positioning System (GPS)

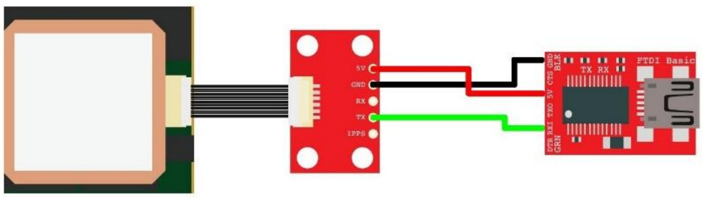
A GPS receiver estimates the geographic coordinates of itself using triangulation, by knowing the time difference of arrival of CDMA encoded radio signals from a number of satellites in mid earth orbit.

It outputs the position estimate using NMEA 0183 encoded TTL RS232 Serial messages so it can be read by a computer.

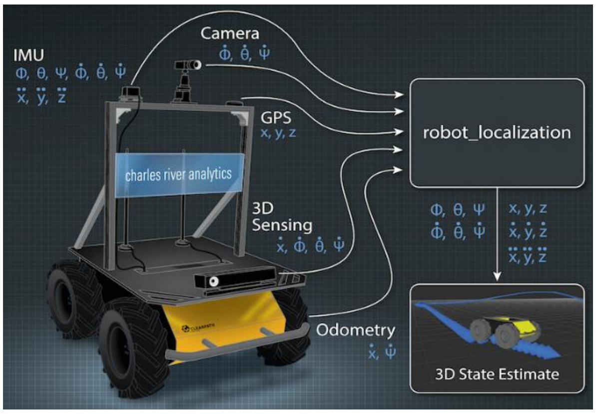
I plan to use a GPS receiver to allow the robot to navigate to desired geographic waypoints set by a remote operator.

USB Serial to TTL Serial Converter

In order to allow the computer on the robot to interpret the TTL serial signals output by the GPS receiver, a USB to TTL Serial converter is required.



Sensor Fusion using Kalman Filter



In order for the robot to estimate where it is, data from several sensors (Including: motor encoders, IMU, GPS, camera) have to be combined.

A Kalman filter algorithm dynamically determines the reliability of each of the sensor updates, and then using this data determines how much weighting to give each sensors measurement in order to reliably estimate the position of the robot.

ROS

Robot Operating System (ROS) is an adaptable framework for creating software for robots.

From their website "ROS is a collection of tools, libraries, and conventions that aim to simplify the task of creating complex and robust robot behaviour across a wide variety of robotic platforms."

Their intention is to develop a robust, adaptable, general-purpose framework for developing software to run on robots.

They provide tools, libraries and conventions, preventing roboticists from: "reinventing the wheel", i.e. unnecessarily rewriting a: suitable, already existing piece of robot software entirely from scratch, for each robot.

The open source model that they use encourages progression in the robotics industry, allowing roboticists to build upon each other's work.

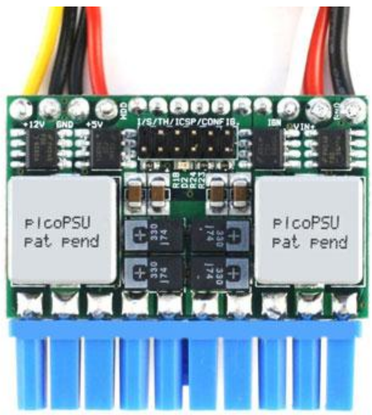
ROS includes tools for robot autonomous navigation (Path planning and object avoidance) and localisation, including SLAM and Kalman Filter (See previous research for more information). They support thousands of various sensors and actuators.

Computer

A larger x86-64 computer (the same type of processor you would find in a desktop or laptop) running the ROS framework could be used on the project to handle tasks which are to computationally difficult for a small microcontroller to process, for example: processing the 3D RGB-D camera and 2D LIDAR images, performing SLAM, running the Kalman filter state estimation, performing trajectory planning and navigation and also running a web interface.

A high performance per watt processor would be the most ideal for compromising between robot battery life and robot performance.

Computer Power Supply

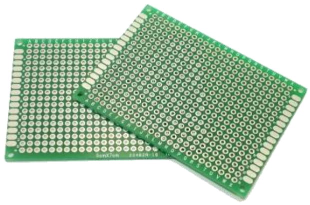


A car PC power supply could be used, which provides power via the standard ATX interface from an input of 6-36V, providing 12V, 5V and 3.3V output rails.

Car PC power supplies also can provide a safe shutdown feature, "softly" shutting down the computer by emulating a power button press, waiting for computer to turn off, then automatically cutting power without damaging the computer.

Alongside powering the computer itself, these voltage outputs could also be broken outside of the computer to power external devices (sensors etc.) that require these common voltages to run.

Prototyping board

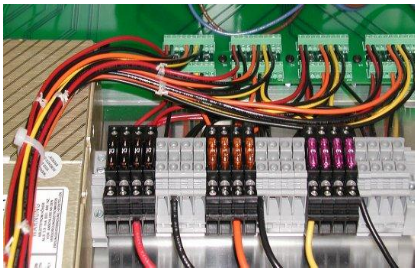


A Prototyping board (also known as a protoboard or veroboard) is a fibreglass board with copper pads and holes designed to mount 2.54mm through-hole electronic components.

Resistors

Resistors are passive two terminal electronic component used to reduce the flow of current and drop the voltage in an electric circuit by converting electrical energy to heat energy.

Fuses



Fuses are sacrificial safety devices which prevent excessive current above a rated threshold.

Fuses are effectively resistors with very little resistance, fuses will physically overheat when the threshold current is reached, causing an open circuit, it will then need to be replaced.

I plan to use fuses for over-current protection on all battery and other power connections.

Screw Terminals

Screw terminals allow the easy connection of large wires, they are especially useful for distributing power cables.

I plan to use terminal blocks to distribute the power throughout the robot.

Ingress Protected Polarised Connectors

Polarised connectors allow the easy connection and disconnection of cables, only allowing mating when both connectors are orientated in the right direction. I plan to use polarised wire-to-wire and wire-to-board connectors on all wire connections throughout the robot allowing easy serviceability and maintenance.

LED

LED is an acronym for light emitting diode, they emit light when voltage is applied. LED's can easily be damaged without a supporting resistor to prevent excessive current flow.

Cable Glands

Cable glands are used to tidily route cables through a panel or surface providing strain relief and also ingress (dust and water) protection with rubber seals and O-rings.

Stand-offs

Stand-offs are plastic or metal spacers available in various sizes which can be used to mount: sheets (e.g. aluminium or acrylic) or circuit boards above a flat surface.

Selection and Justification of Appropriate Materials, Processes and Resources

Parts

Selection of chassis frame material

Type	Advantages	Disadvantages	Plan to Use?
Aluminium (Box and angle section)	• High strength to weight ratio • Non-Corrosive • Can be anodised • Can be powder coated • Is flexible	• Can easily be dented or deformed • Can easily shear • Harder to weld	✓
Steel (Box and angle section)	• Strong • Can be powder coated • Easy to weld	• Low strength to weight to weight ratio • Non-resilient (brittle, not very flexible) • Corrosive	✗

Justification of chassis frame material selection

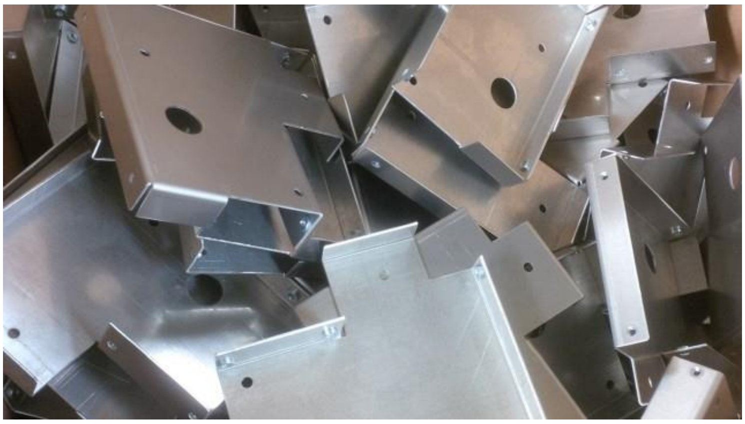
I plan to use aluminium to construct the chassis because it is a light, non-corrosive material.

Selection of enclosure lid material

Type	Advantages	Disadvantages	Plan to Use?
Aluminium	• Lightweight	• Can easily be dented or deformed	✓
Fibreglass	• Can be Moulded into any shape • Lightweight • Strong	• Fibres can break off and become airborne	✗

Justification of enclosure lid material selection

I plan to get the lid of the enclosure fabricated from aluminium, because I am unfamiliar with the processes involved in fibreglass construction.



Selection of panel material

Type	Advantages	Disadvantages	Plan to Use?
Aluminium Sheets	• Can be anodised or powder coated • High strength to weight ratio	• Can easily be dented or deformed	✓
Acrylic Sheets	• Available in: Transparent, Glossy, Translucent or opaque styles	• Brittle	✓

Justification of Panel Material Selection

I plan to use aluminium sheets for panels holding excessive weight on them, and coloured acrylic sheets for panels that are not.

Selection of Computer Data acquisition and GPIO controller

I have made a comparison table for all the processor options I have found available, for more details on the function of the processor, see the research section above.

Type	Advantages	Disadvantages	Plan to Use?
8 Bit Microcontroller	• Comes in through hole packages • Extremely easy to program	• Comparably Slower than other options	✓
32 Bit Microcontroller	• Easy to program • Fast	• Only Surface mount packages available	✗
Field Programmable Gate Array (FPGA)	• Extremely Fast because of hardware logic	• Only surface mount packages available • More difficult to: integrate into design, program and use.	✓
Complex Programmable Logic Device (CPLD)	• Extremely Fast because of hardware logic	• Only surface mount package available • Hard to integrate into design, program and use.	✗

Justification of Computer Peripheral Interface Selection

I plan to use an AtMega328 8 bit microcontroller to control the motors because it's cheap and easy to program, and an FPGA to read the quadrature feedback signals from the wheel encoders to determine the speed and relative position of the motors.

Selection of Computer

Type	Advantages	Disadvantages	Plan to Use?
Single Core ARM	• Inexpensive • Low Power Consumption	• Complicated driver and software support	✗
Multi Core ARM	• Relatively inexpensive • High Performance-per-watt • Low power consumption	• Complicated driver and software support	✗
x86 Computer	• Easy to source • Good driver and software support • Powerful	• Expensive • High power consumption • Large Motherboard	✓

Justification of Computer Selection

I plan to use a dual core Intel x86 based computer because they are very accessible and easy to configure.

More specifically I plan to use a Gigabyte Mini ITX motherboard with an Intel 3330T (T meaning high performance per watt) processor and solid state drive to reduce power consumption in an effort to improve battery life.

The motherboard also includes a Wi-Fi chipset allowing connection to wireless networks.

Selection of Motors

Type	Advantages	Disadvantages	Plan to Use?
Bipolar Stepper	• Large amount of torque • Precise open loop position control.	• Moderate Weight • Comparably slow rotation • Uses Rotating electrical contacts	✗
DC Gear motor	• Large amount of torque	• Moderate Weight • Comparably slow rotation • Uses Rotating electrical contacts • No position Control	✓
Brushless DC Motor	• Light Weight • Extremely fast angular velocity • Limited position control available • Extremely efficient • Long life because of less electrical parts • Large Amount of torque	• Expensive • Hard to control.	✗

Justification of Motor Selection

For the drive system I decided to use Large DC Gear motors with a planetary gearbox and quadrature encoder feedback.

The encoders can used for closed loop velocity control and position feedback (more information in the research section under motor feedback).

Selection of Batteries

Batteries are often an overlooked part of a project, but in the case of a mobile robot I have found in my research they are heaviest component and that energy-to-weight and energy-to-volume density are absolutely crucial.

Type	Advantages	Disadvantages	Plan to Use?
Lead-Acid	• Easy to charge • Easy to source	• Extremely Heavy • Low Energy-to-volume Density • Low Energy-to-weight Density	✗
Lithium-Ion	• Extremely high energy-to-volume density • Extremely high energy to-weight density • Extremely high charge and discharge rate • Easy to source	• Expensive • Difficult to charge, requires cell balancing	✓
Nickel Metal Hydride	• Reasonably High Discharge rate • Reasonably high energy to-weight density	• Hard to source • Expensive • Difficult to charge	✗

Justification of Battery Selection

I plan to use Lithium Ion batteries because they have an extremely high: energy-to-weight and energy-to-volume density, charge and discharge rate.

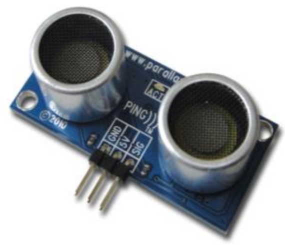
I will need to implement a lithium battery cell management circuit to ensure the cells are equally balanced, this will prevent damage to the cells, increasing the life and also ensure they will not explode.

Selection of Proximity Sensors

Type	Advantages	Disadvantages	Plan to Use?
SONAR	• Cheap • Very simple and accurate	• Slow update rate, due to the speed of sound • Susceptible to interference from ultrasonic sound • 1 Dimensional	✓
2D LIDAR	• Very Accurate • Very Fast • 2 Dimensional	• Complicated • Expensive • Susceptible to interference from the sun	✓
Infrared Distance Sensor	• Very Accurate • Very Fast	• Expensive • Susceptible to interference from the sun • 1 Dimensional	✗
RADAR	• Very Accurate	• Complicated • Expensive • Susceptible to interference from other radio waves • 1 Dimensional	✗

Justification of Proximity Sensor Selection

I plan to use a 2D LIDAR for a high quality 2D scan of the environment, with Sonar Proximity sensors to cover the vertical blind spots of the cross sectional LIDAR scan.



Selection of Solder type

Type	Advantages	Disadvantages	Plan to Use?
Lead Free	• Non-Toxic, much safer than leaded alternatives	• Higher Melting temperatures • Harder to source materials, therefore more expensive • Doesn't flow as well as leaded solder	✓
Leaded	• Lower Melting temperatures • Easy to source materials, therefore cheaper • Much easier to use than lead free solder	• Toxic If large enough quantity is absorbed by the body	✗

Justification of Solder type Selection

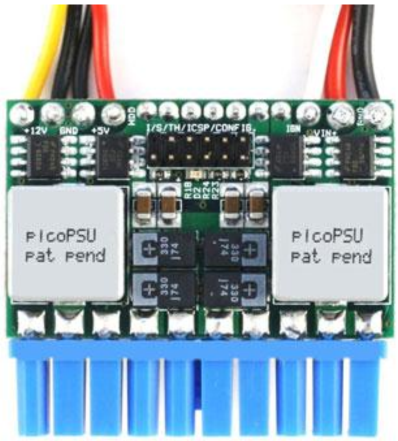
I plan to use lead free solder on this project because it is a less hazardous substance, therefore much safer, Lead-Free solder is a little bit harder to work with; the joints are not as tidy and it has a higher melting temperature, but safety is always the greatest concern.

Selection of Step-Down Power Supply

In order to power electronic components/modules that run off lower voltages then the batteries provide, a step down power supply is required.

Type	Advantages	Disadvantages	Plan to Use?
Switched mode Power Supply	• Allows More Current • Extremely efficient	• More complicated circuit • Requires an external inductor • More expensive • Susceptible to EMR noise on exposed high frequency traces	✓
Linear Voltage Regulator	• Cheap • Very Simple circuit	• Inefficient • Allows Less Current • Dissipates a lot of heat when supplying large amounts of power.	✗

Justification of Step-Down Power Supply Selection



I plan to use a switched mode power supply because it is much more efficient than using a linear regulator, less electrical energy will be dissipated as heat, which in turn results in a cooler operating temperature and longer battery life.

The M3-ATX-HV seems to be a powerful and efficient switched mode power supply, which can be used to directly power the computer using the ATX connector and also other external electronic components and/or modules directly from a Molex connector.

Selection of motor driver

The motors are expected to draw a 30A of current peak, causing large amounts of energy as heat to be dissipated on the MOSFETS on the H-Bridge that control the motors, a large heat-sink is necessary to prevent damage due to overheating.

Type	Advantages	Disadvantages	Plan to Use?
Assemble H-Bridge on veroboard	• Inexpensive	• Traces could be easily destroyed by extreme voltage and current surges generated by the motor • Physically Large because of through hole construction	✗
Sabertooth 2*25 Motor Driver	• 5V RS-232 TTL Serial interface • Small because of SMD construction • Designed to handle excessive back-EMF and peak currents of 50A per channel • Includes a metal heat-sink to dissipate heat	• Expensive	✓
Sparkfun "Monster Moto" Dual H-Bridge VNH2SP30 driver	• Designed to handle excessive back-EMF and peak currents of 30A per channel • Comparatively less expensive than Sabertooth	• Cannot Handle above 16V continuous • No heatsink	✗

Justification of Motor Driver Selection

I would like to construct an H-Bridge Circuit myself, but because of the sheer size of the motors, the H-Bridge would need extremely large MOSFET's capable of withstanding:

- Current spikes in excess of 30A
- Transient voltage spikes from sudden motor stopping/changing direction in excess of Several Hundred Volts
- PWM Speed Control in excess of 15Khz (66.67 microseconds switching time)

This would make it really hard to maintain the motor diver if I were to damage a MOSFET due to a large current or transient voltage spike.

It would be much simpler, much tidier, more maintainable, more robust and more reliable to use a commercial high power H-Bridge motor driver board for this project.

I plan to use a Sabertooth 2*25 motor driver because it is a small, powerful and robust motor driver with a TTL serial interface.

Selection of Drive System/Wheels

Type	Advantages	Disadvantages	Plan to Use?
Pneumatic (rubber with air tube) wheels	• Extreme amount of traction (indoor/outdoor) • Absorbs Shock when slightly deflated	• Heavy • Only come in large diameters • Require gearing down with chain or timing pulley OR a large (heavy, high current) motor • Requires inflation every couple of months	
Polyurethane wheels	• Reasonable traction indoors • Lightweight • Direct drive from motor	•	
Hard Plastic wheels	• Lightweight • Direct drive from motor	• Very little traction	

Justification of Drive System/Wheel selection

I plan to use 200mm polyurethane wheels which have an 8mm shaft to fit the motors directly.

The wheels are suitable size to be driven with the motors I have selected (16kg-cm stall torque).

Tools and Machinery

Soldering Station

In this project I plan to use a soldering Iron to: connect the electronic components to the various circuit boards throughout the robot, and also to join wires in places where a connector is unnecessary. (The process of soldering is further explained below in the processes selection)

Side Cutters

Side cutters are a small plier like tool with cutting blades

In this project I plan to side cutters to:

- Cut leads off components
- Cut Wires

Solder Wick

In this project I plan to use solder wick to de-solder any solder joints with too much solder or are bridged and shouldn't be.

Metal File

In this project I plan to file down all the sharp metal edges for safety using a file.

Spanners

In this project I plan to use spanners to tighten or loosen external nuts and bolts

Socket Set

In this project I plan to use a socket set to tighten nuts and bolts in locations inaccessible with a regular spanner or shifter.

MIG Welder

In this project I plan to have a third party fabricate the robot chassis using a MIG (Metal Inert Gas) welder since I do not have experience with a welder nor access to one.

Angle Grinder

In this project I plan to use an angle grinder to grind and cut the metal on the robot prior and posterior to the fabrication.

And also for partially finishing the metal surfaces, removing any defects or protrusions which may have an effect on the quality of the project/painting.

I have access to an angle grinder at home.

Screwdrivers

In this project I plan to use a screwdriver to fasten and/or unfasten screws on:

- The computer enclosure
- The motors
- Screw terminals

Bandsaw

In this project I plan to use a bandsaw to cut the aluminium and aluminium sheets, which are too thick for the laser cutter that I will be using to penetrate.

I have access to a Band Saw at the Robots & Dinosaurs makerspace located in the north-western suburbs of Sydney and previous experience using it.

Automatic Wire Strippers

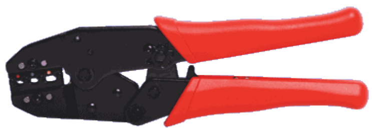
I plan to use automatic wire strippers to strip wires on the project.

These provide a benefit over side cutters of not applying a tension force to the wire being stripped, ensuring it doesn't damage what is attached to the other end of the wire.

Crimper

In this project I plan to use crimpers to attach connectors to wires, allowing modules of the electronics within to be easily removed in future for maintenance.

For automotive connectors



In this project I plan to use an automotive crimp tool to crimp connectors for power wring on the fuses and relays.

For bootlace ferrules

In this project, I plan to use bootlace ferrules to neatly terminate stranded core wires that get attached to screw terminals. These require a bootlace ferrule crimper.

For Deutsch brand ingress sealed connectors

In this project I plan to use Deutsch brand Ingress sealed connectors, because they are of a high quality. I have Deutsch a crimp tool and connector kit already at home.

Air Compressor

In this project I plan to use an air compressor to power the Pneumatic Belt sander. I have access to a 2.5hp shop air compressor at home.

Pneumatic Belt Sander

I plan to use a pneumatic belt sander for finishing the metal surface of the chassis, removing any defects or protrusions which may have an effect on the quality of the painting.

Specifically a Pneumatic belt sander can be fit into confined spaces that a regular belt sander would not fit into.

I have access to a pneumatic belt sander at home.

Paint Gun

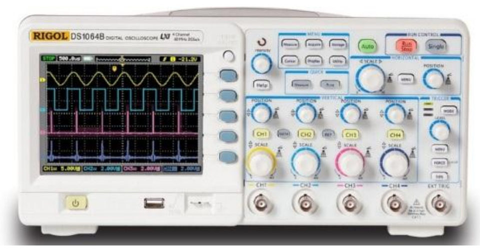
In this project I plan to have the chassis and wheels professionally painted using a Paint Gun by a third party, since I have no experience with high quality painting nor access to a spray gun.

Heat Gun

In this project, I plan to heat-shrink all wire to wire connections using a heat gun. I have access to an electric heat gun at home.

Digital Oscilloscope

In this project I plan to use a digital oscilloscope to: help debug any issues regarding electrical noise on digital signals and also monitor analogue signals.



A digital oscilloscope allows me to capture signals and play back the waveform on the display.

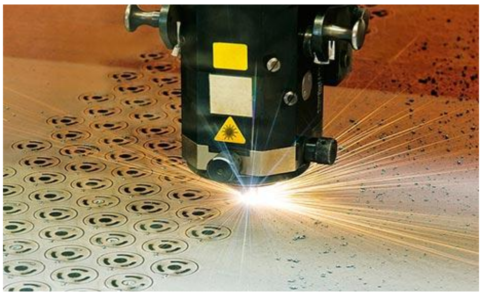
I have access to a digital oscilloscope at home.

Logic Analyser

In this project I plan to use a logic analyser to help troubleshoot any digital signals, allowing me to record the signal and convert the binary data being transmitted (using i2c, SPI and UART protocols) to easily readable text on a computer screen.

I have access to a logic analyser at the Robots & Dinosaurs makerspace located in the north-western suburbs of Sydney and previous experience using it.

Laser Cutter



A laser cutter is a machine which uses a high powered laser to cut through or engrave material.

The laser is mounted on an XY gantry, the position is actuated by motors. The motor speed and position and also beam power is computer numerically controlled.

A 2D CAD design can be loaded into the machine and it will cut the design out of material (generally acrylic or wood, high power laser cutters can also cut aluminium).

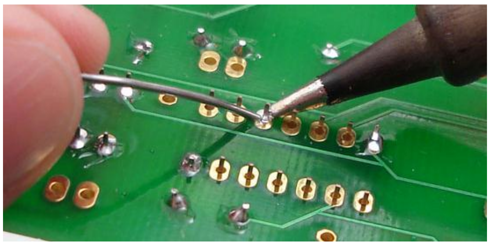
It is much more time efficient, precise and repeatable to design the acrylic panels using CAD then cut the designs on a Laser Cutter compared to manually cutting them.

If I were to build another robot in future, I could just load in the same design files for the acrylic panels into the laser cutter and cut them identically.

I have access to a laser cutter at the Robots & Dinosaurs makerspace located in the north-western suburbs of Sydney and previous experience using it.

Processes

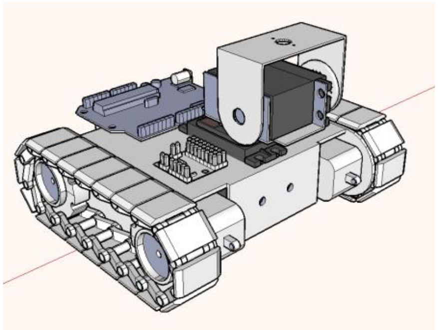
Soldering



Soldering is a technique of melting a fusible metal allowing connection of two (or more) pieces of metal using heat.

I plan to solder all the electrical connections on the circuit boards.

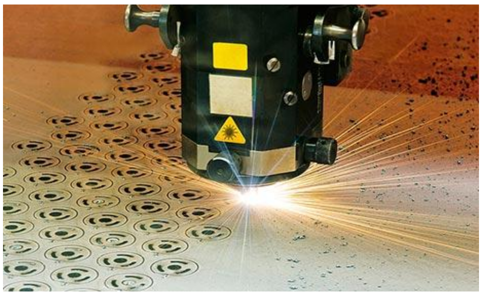
Computer Aided Design



Computer Aided Design (CAD) is the process of using of computer technologies to produce drawings.

I plan to make the Mechanical working drawings using 2D and 3D CAD Drawings.

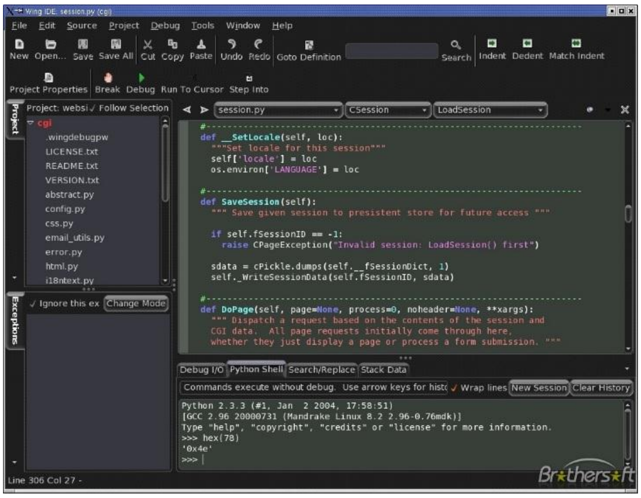
Laser Cutting



I plan to design all the panels (switch panel, side panels) in CAD and personally operate a laser cutter (operation described in Tools and Machinery section above) out of a sheet material, possibly acrylic sheet.

I have access to a 60W Laser Cutter at the Robots & Dinosaurs makerspace located in the northern suburbs of Sydney and previous experience using it.

Software Development

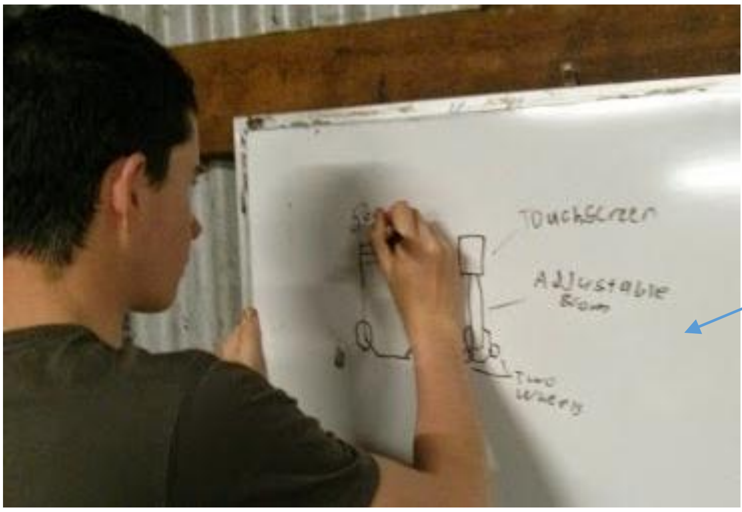


Software Development is the process of creating, documenting and maintaining computer software.

I plan to write all the software on the microcontroller and possibly some other software required to achieve the extensions to the task listed in the statement of intent as “only if time permissible”.

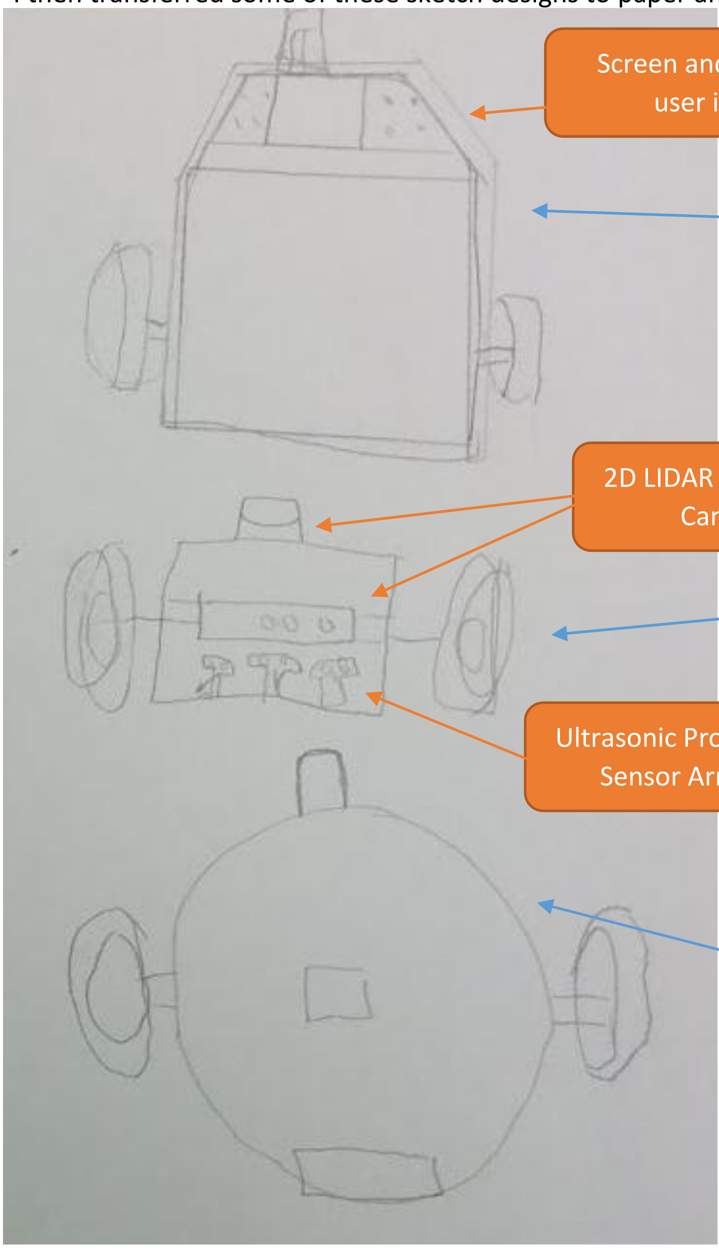
Development of Ideas, Sketching and Idea Generation, Prototyping, Modelling and Testing, Production and Working Drawings

Development of Ideas and Sketching and Idea Generation



I started sketching possible designs of this project on my whiteboard, iterating through different design ideas and making improvements.

I then transferred some of these sketch designs to paper and compared them



Screen and pushbutton user interface

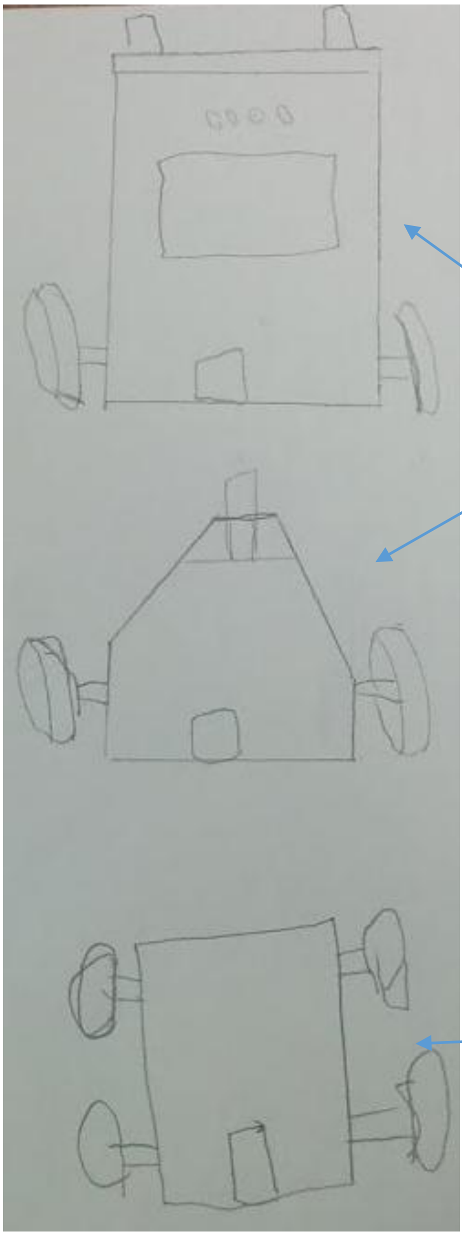
Top view sketch, one of my robot design Ideas. With two drive wheels and a trailing caster wheel.

2D LIDAR and RGB-D Camera

Front view sketch, one of my robot design Ideas. Showing possible placement of sensors

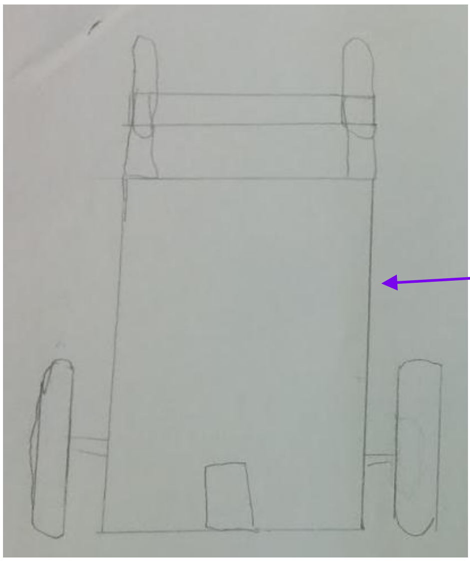
Ultrasonic Proximity Sensor Array

Top view sketch, one of my robot design Ideas. Alternate circular chassis design.



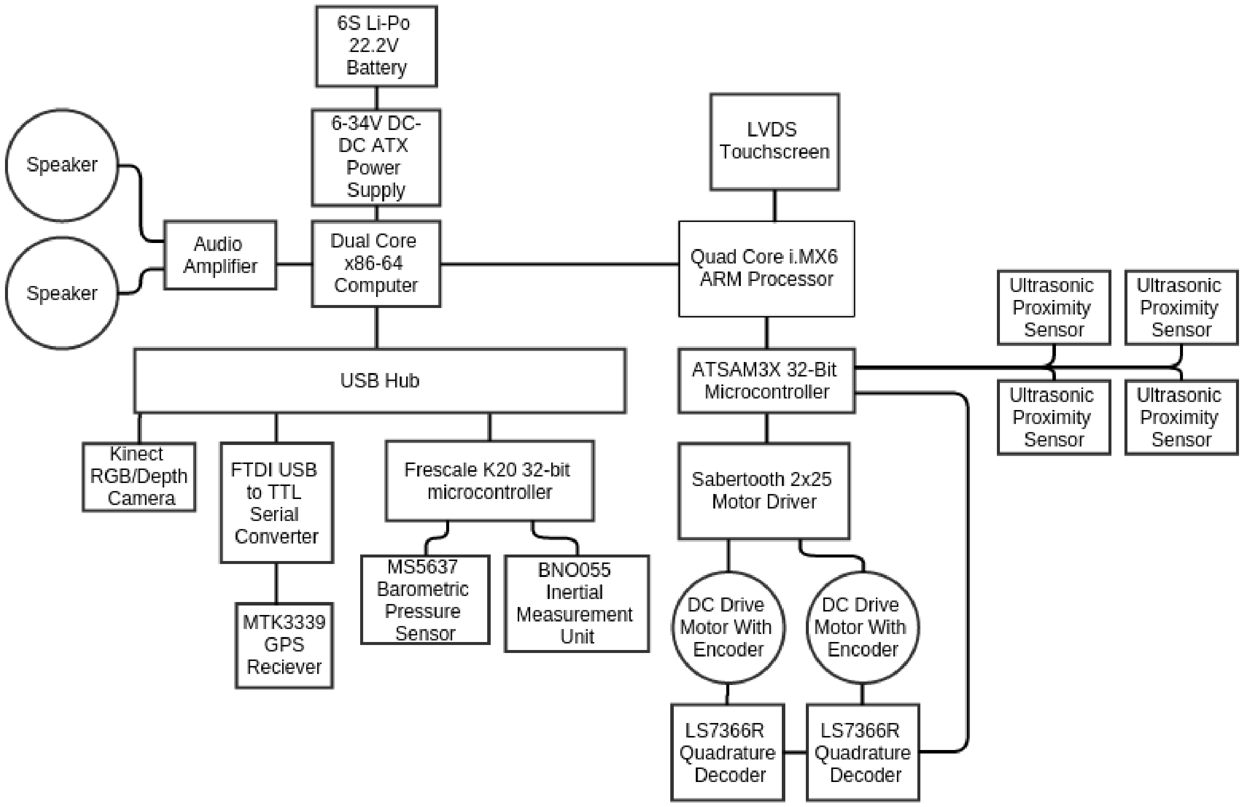
Top view sketches, some alternate robot chassis design Ideas.

Top view sketch, an alternate robot chassis design Idea, with four drive wheels and skid (bobcat style) steering

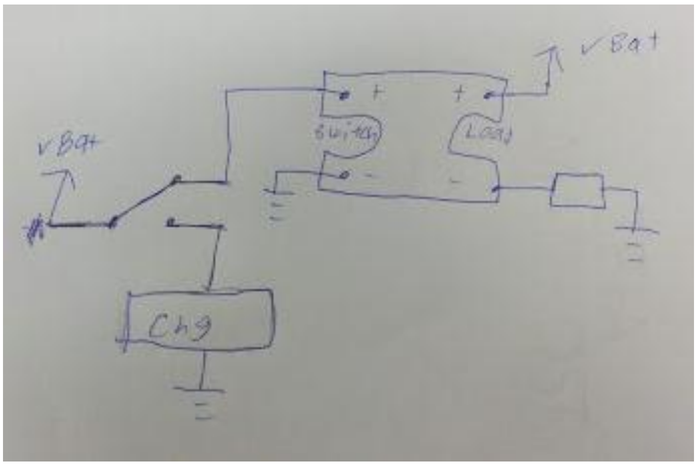


I decided to settle for this rectangular design, with two drive wheels and two caster wheels.

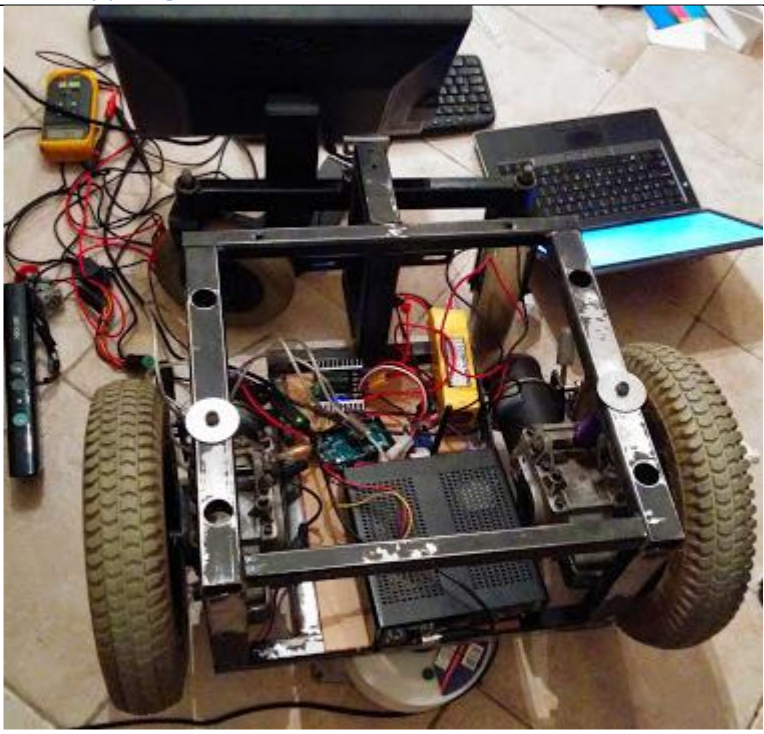
I also drew basic block diagram overview of the topology of the electronics on the robot using a Computer Aided diagram tool.



Throughout the project production section I skeched up an array of diagrams allowing me to develop my ideas and giving me some reference/guidance as I worked



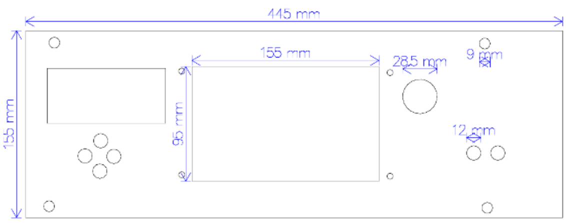
Prototyping



I started prototyping by test fitting (non permanent mounting) the majority of the electronic parts onto the robot, allowing me to configure and test the microcontrollers, the sensors, the motor rotation (note: the robot is chocked up on blocks) and also ensure all the voltage rails were as expeced.

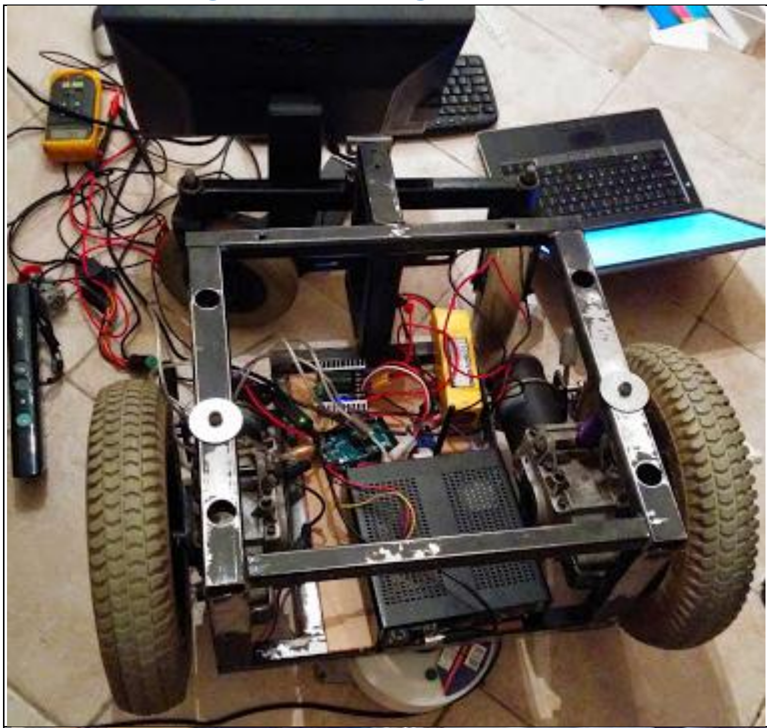
Having access to a laser cutter allowed me to quickly prototype a face plate for the control panel out of scrap plywood, and then I could test fit the screen, buttons and switches. It allowed me to see if the panel design was ergonomic.

Because of this ability to partake in rapid prototyping, I have now been able to redesign the panel making improvements.

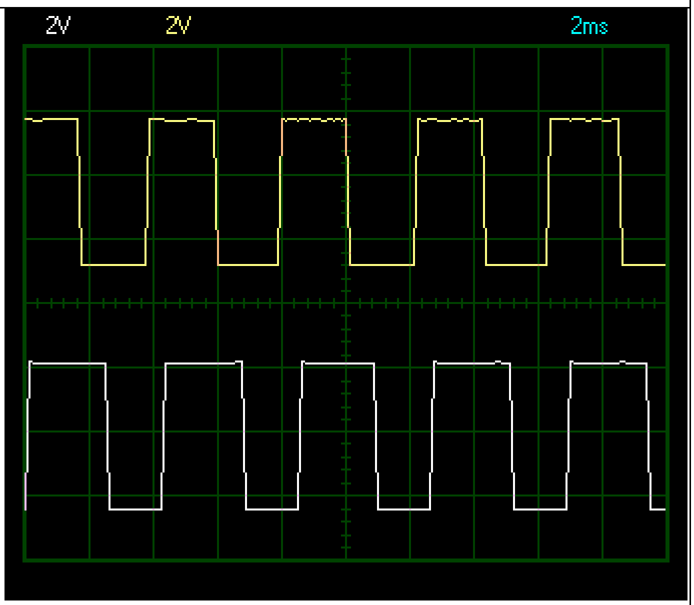


I was able to prototype the motor control, computer and various sensors, by driving it around the schoolyard using a remote controled joystick, ensuring that everything worked as expected.

Modelling and Testing



During the prototyping stage I was able to test and measure the motor current and all the voltage rails using a multimeter, ensuring that everything was as expected.

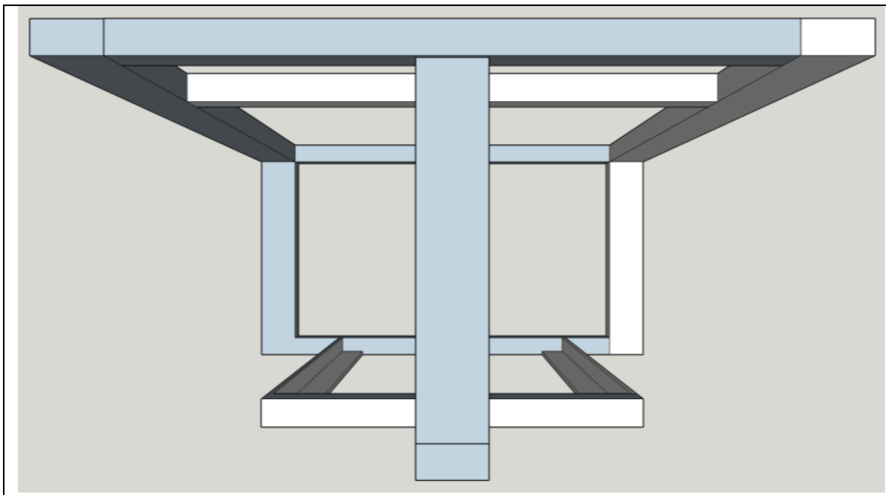
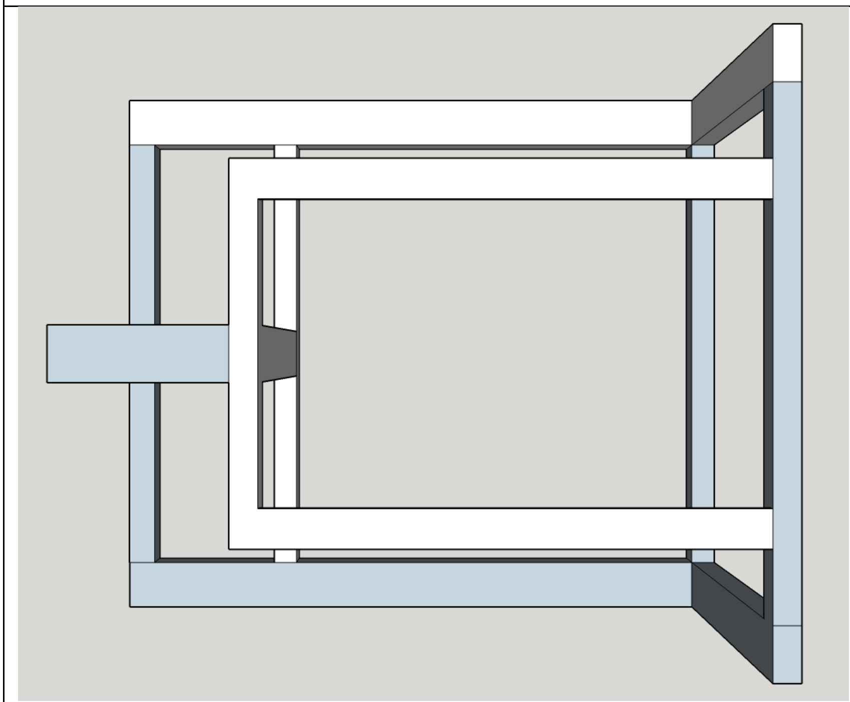
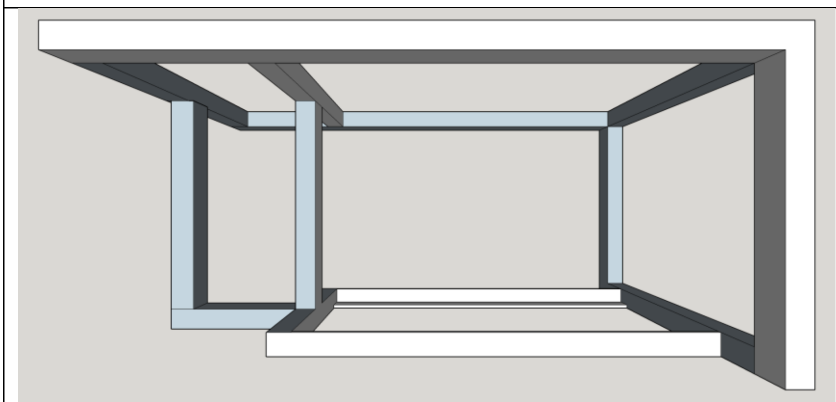


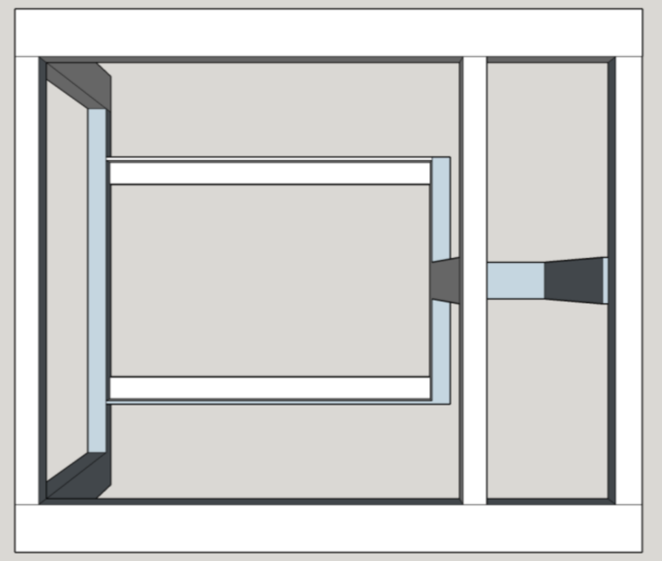
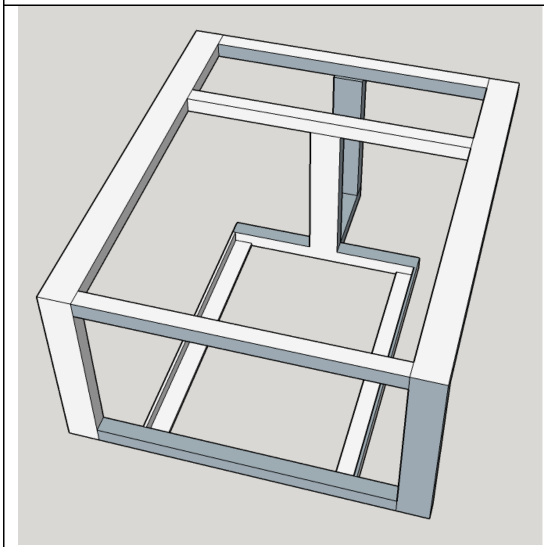
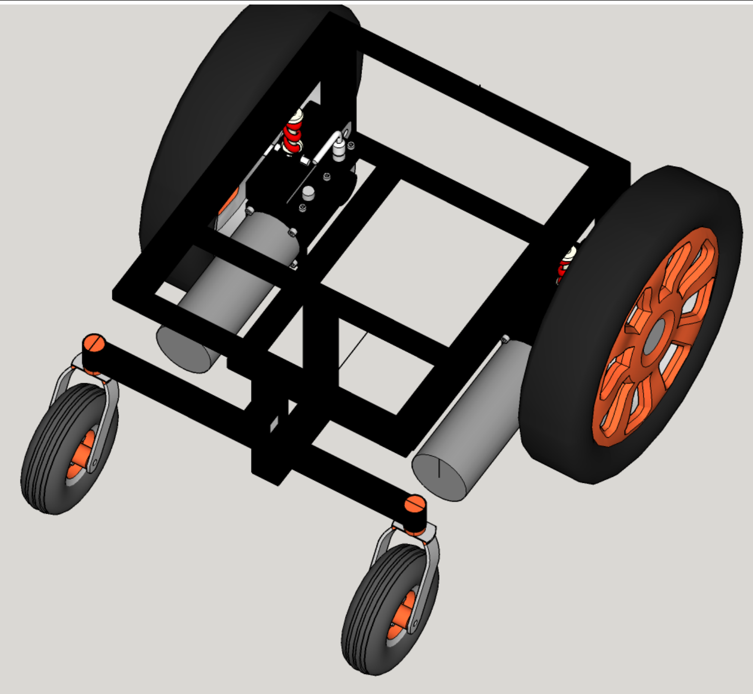
Using an oscilloscope, a tachometer and a calculator, I was able to measure the quadrature feedback signals coming from the motors (shown in screenshot above) and determine the number of electrical pulses per revolution of the motor shaft (I calculated 22885 pulses/revolution).

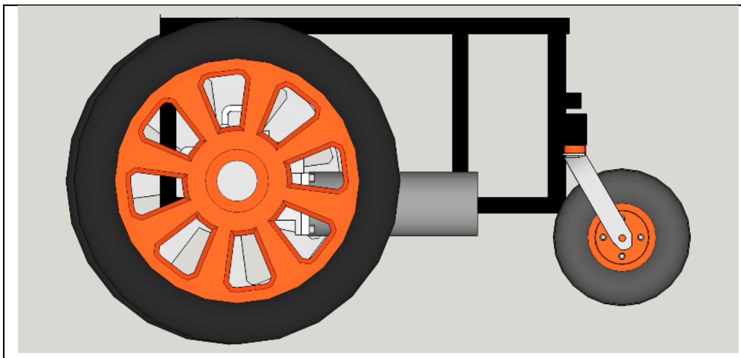
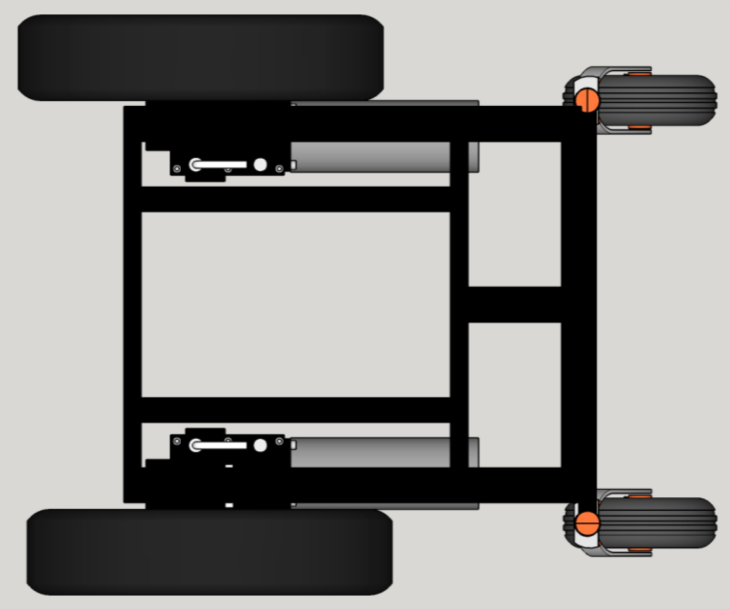
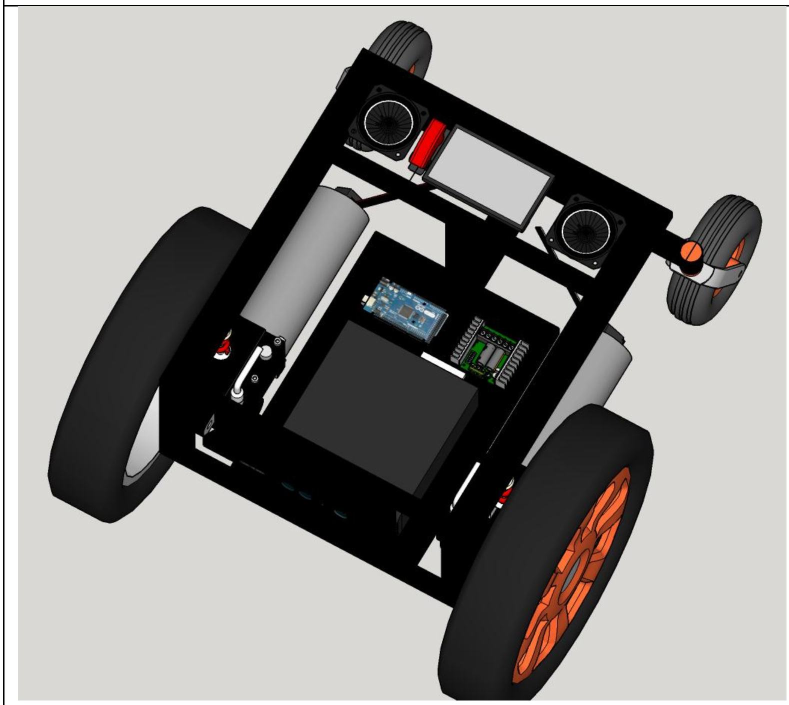
I was also able to determine the average rotation rate of the shaft at 22.2V (my battery voltage) is 2.05 Revolutions per second with no external load on the motor.

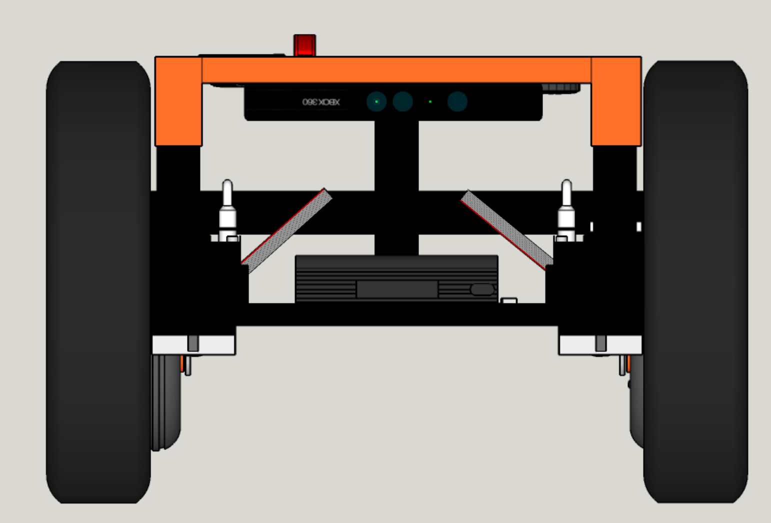
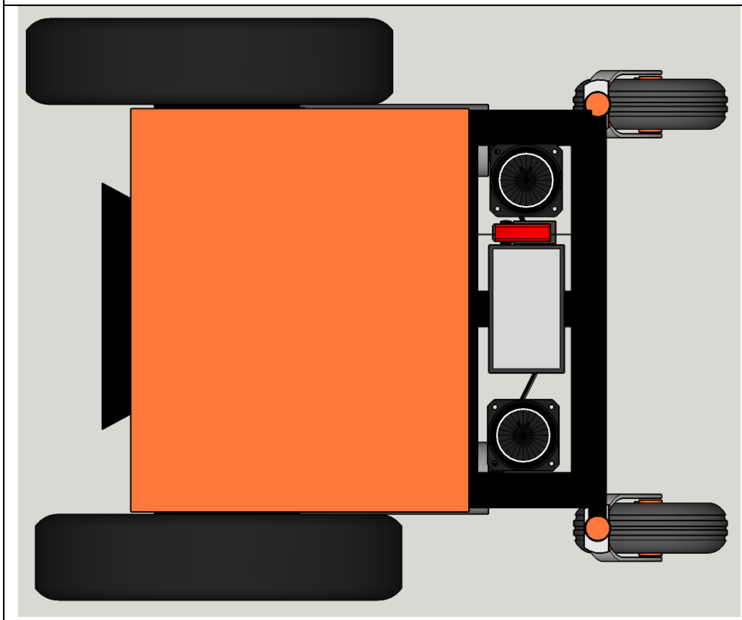
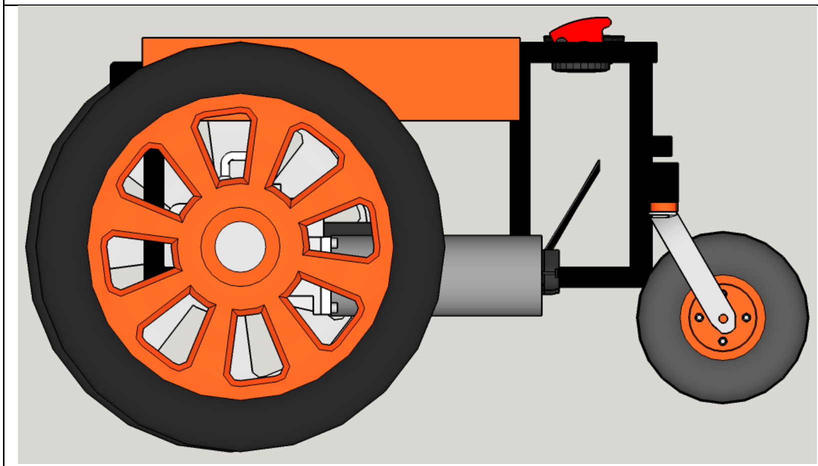
Production and working drawings

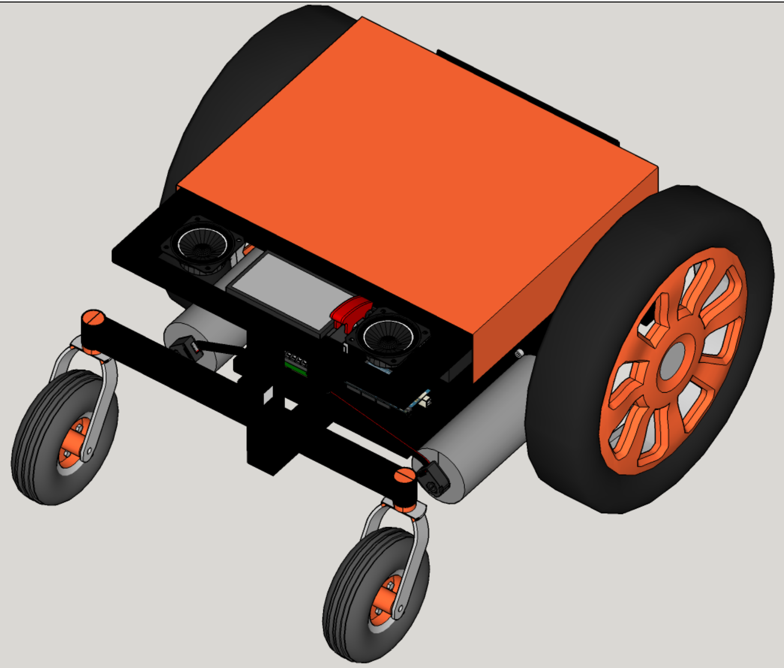
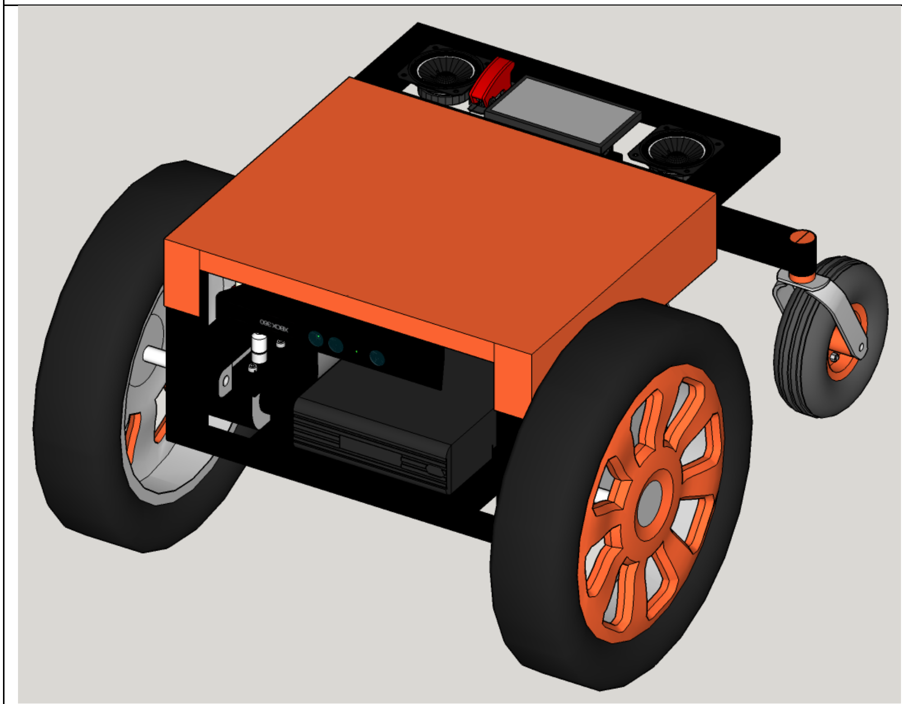
On the next few pages are some working drawings of the robot frame and progressively being fitted with wheels, motors and electronics, it also demonstrates a possible two tone orange and black paint scheme.

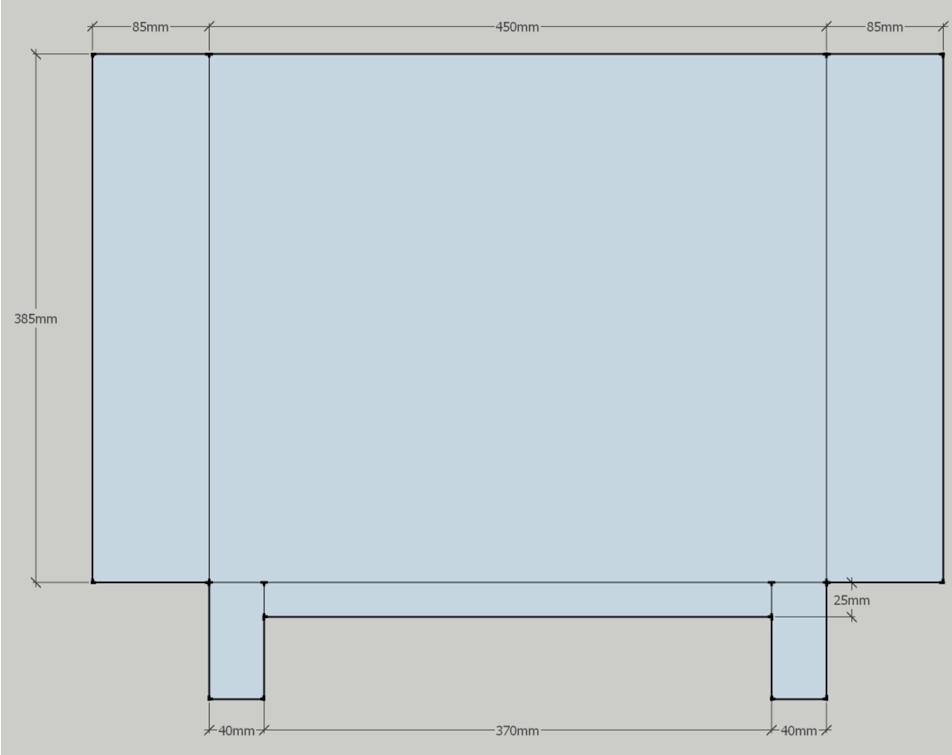
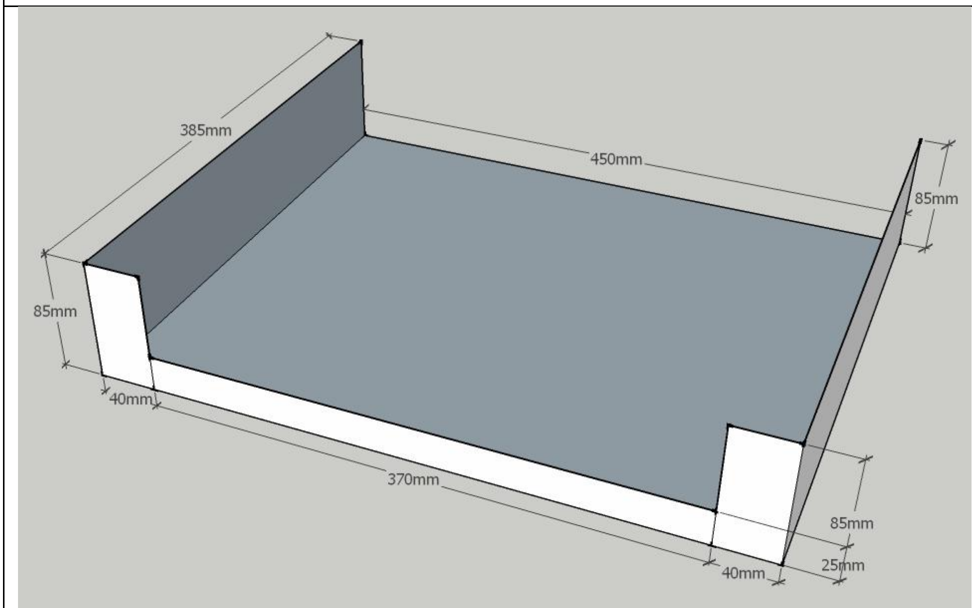
	Back View of the Wheelchair Frame
	Bottom View of the Wheelchair Frame
	Side View of the Wheelchair Frame

	Top View of the Wheelchair Frame
	Tilted View of wheelchair Frame
	Wheelchair Frame Painted Black Motors, wheels and suspension mounted. Painted orange Highlights.

	Side View of Frame, wheels and motors.
	Top View of Frame, wheels and motors.
	Tilted View of painted wheelchair fitted with electronics, including: • Computer • Motor Driver Board • Kinect RGB/D Camera • Power Switch with protective cover • Microcontroller board • Stereo Speakers

	Front view of robot with orange painted aluminium cover fitted and also electronics listed above
	Top View of fitted out robot
	Side view of fitted out robot

	Tilted rear View of fitted out robot
	Tilted front view of fitted out robot

	2D net view of Aluminum enclosure cover.
	3D Tilted View of aluminium enclosure cover.

On the next page are hand drawn dimensioned orthographic projection drawings (top, side and front view) of the robot chassis, I am unskilled and untrained at hand orthogonal drawing, so I organised for it to be completed by a third-party who is skilled at drawing.

Appropriate Design and/or Design Modification

Materials

Instead of using aluminium to construct the chassis, I decided to modify a steel wheelchair chassis.

This made the construction process much simpler, but a compromise was made by making the mass of the chassis much heavier.

Instead of using the Red acrylic for the back panel (shown in some pictures), I decided to use black acrylic, because my original back panel broke in early August, and black was all I could source in time.

Processes

I appropriately selected production processes in my Selection and Justification of Processes section, and used all of the processes that I had originally selected in the design phase of the project.

Technologies

I had to replace the AtMega 328 Microcontroller that I had originally planned to use, with an AtMega 2560 Microcontroller because there were issues with the use of multiple instances of Software Serial ports, the AtMega 2560 fixed this problem because it has multiple hardware UART ports available.

Instead of using an FPGA to decode the quadrature signals from the wheel encoders as I had originally , I decided to use US Digital LS7366R quadrature counter IC's.

Other

Wheelchair Chassis

I decided upon purchasing and modifying a used wheelchair chassis because of time and cost constraints. I wanted more focus on the electronic design rather than the mechanical design.

I realised that apart from being much simpler to build, a used commercial wheelchair base (or similar) would be more suitable because It:

- Includes suspension
- Is much cheaper than buying: raw material, wheels and motors separately
- Has been designed specifically to be maintained easily and taken apart
- Has specifically designed replacement parts available making it very easy to repair in future if necessary

Wheels

I changed my selection of using polyurethane wheels to using Pneumatic rubber wheels when I purchased the wheelchair, because they were already included with the wheelchair and fitted to the motors.

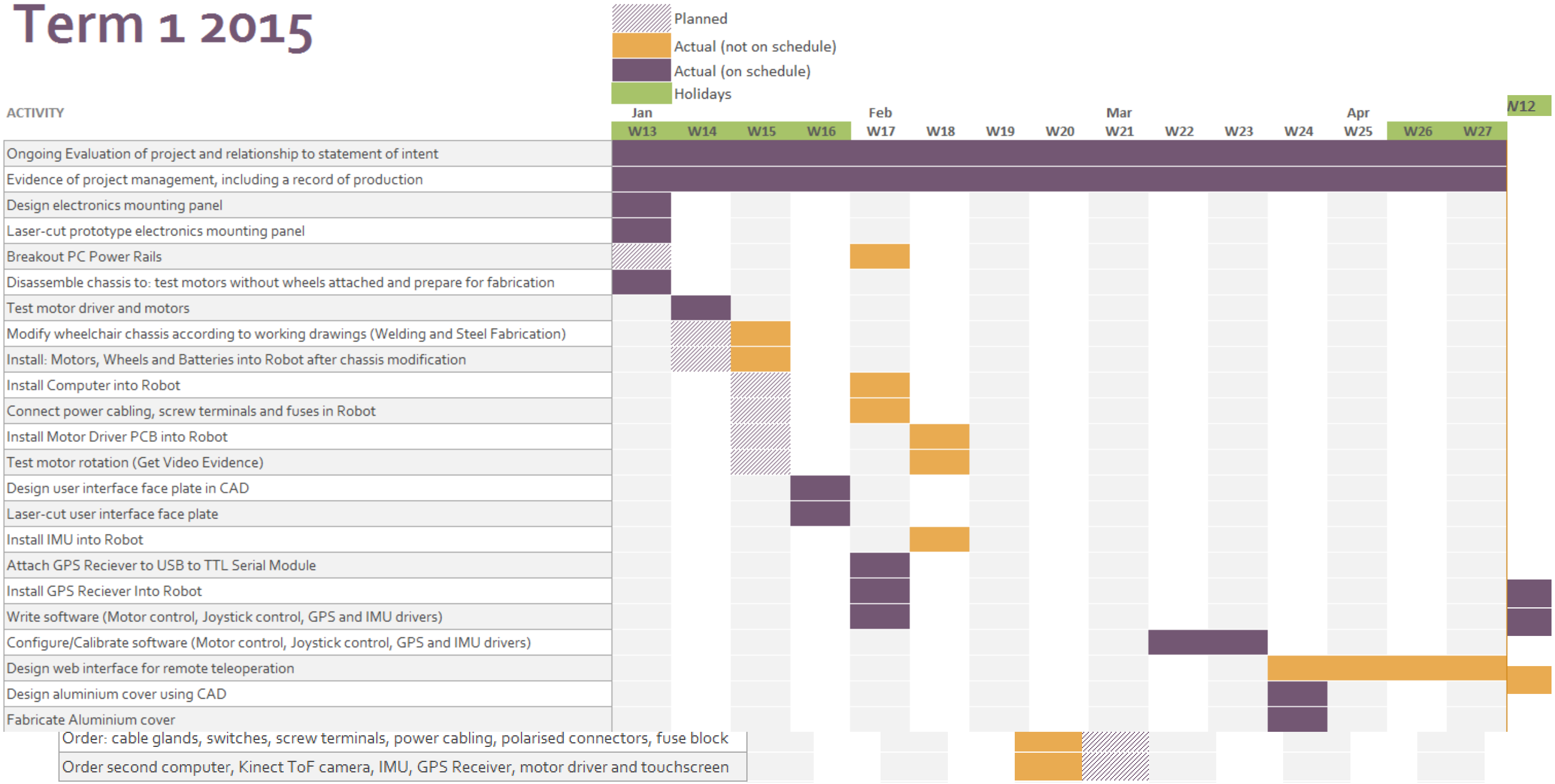
Timeline Plan

I created the timeline plan with a hopefully realistic amount of time for each task and allowing time for troubleshooting to ensure I remain on track. I separated the tasks into three Gantt Charts which can be seen on the next pages.

Justification for changes in the folio can be seen below

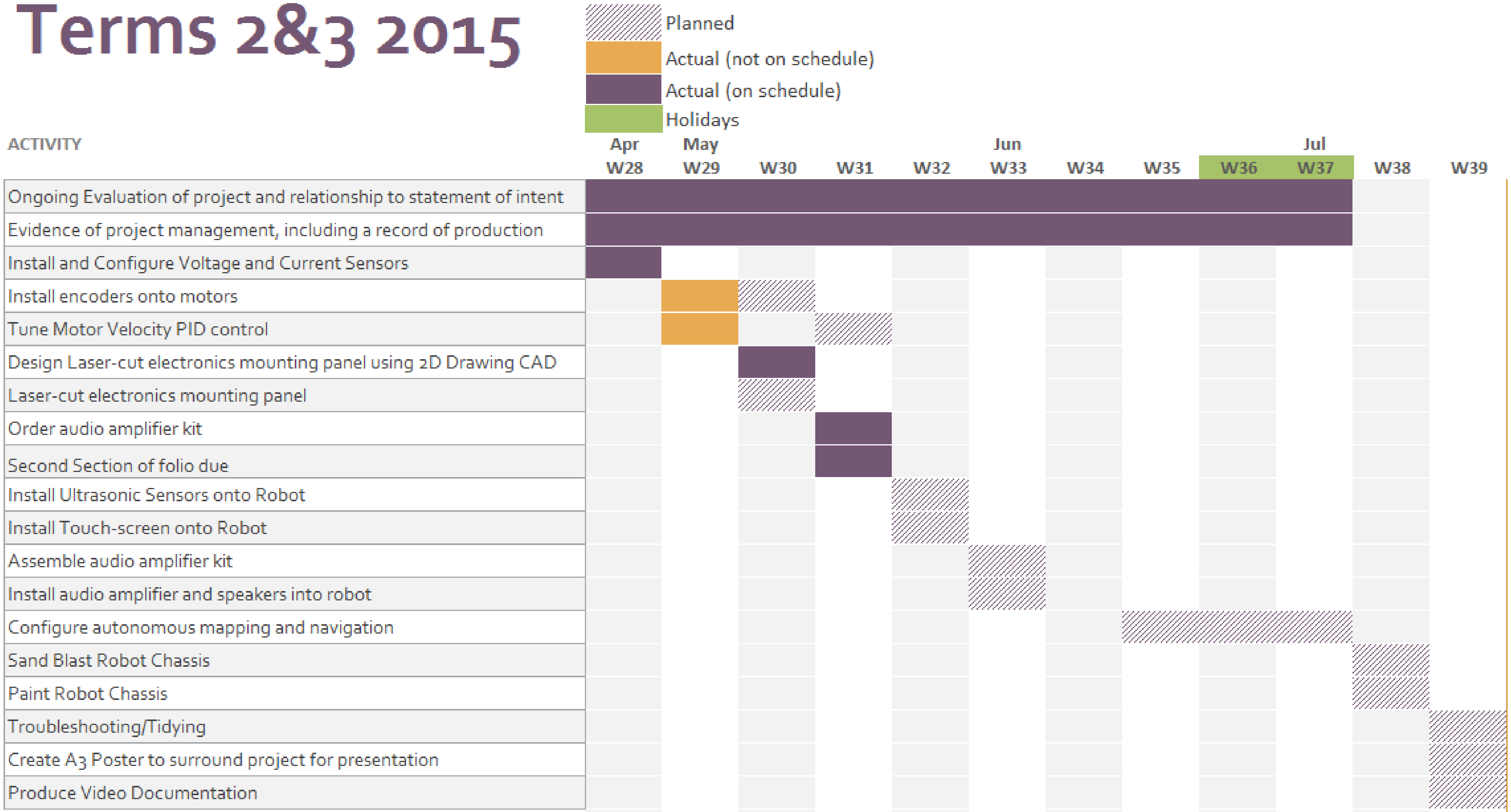
Justification of differences between planned and actual timeline			
Task	Planned Completion	Actual Completion	Justification of differences
Order Motor drivers, purchase wheelchair chassis	Week 4 of project	Week 11 of project	I couldn’t find a reasonable chassis until wk11, I ordered the motor driver with it.
Drawing CAD 3D Working Drawings of chassis	Week 5 of project	Week 12 of project	I had to draw based on the chassis design, I didn’t have the chassis until wk11
Order Battery, aluminium sheet, composite aluminium sheet and acrylic sheets	Week 6 of project	Week 5 of project	I decided to purchase this early so it would arrive earlier and I could start production
Order: cable glands, switches, screw terminals, power cabling, polarised connectors, fuse block	Week 6 of project	Week 5 of project	I decided to purchase this early so it would arrive earlier and I could start production
Order second computer, Kinect ToF camera, IMU, GPS Receiver, motor driver	Week 6 of project	Week 5 of project	I decided to purchase this early so it would arrive earlier and I could start production
Breakout PC Power Rails	Week 13 of project	Week 16 of project	I did not have access to the computer until wk16 because I was away on holidays
Modify wheelchair chassis according to working drawings (Welding and Steel Fabrication)	Week 14 of project	Week 15 of project	I was waiting on the fabricator to be available
Install: motors, IMU, computer, power cabling, screw terminals, wheels and Batteries into Robot after chassis modification	Week 15 of project	Week 17-18 of project	This was delayed also because of the fabrication delay
Install encoders onto motors, configure PID control	Week 29 of project	Week 30-31 of project	I managed to find these encoders in some medical equipment waste a week earlier than I was planning on purchasing them.

Term 1 2015



Planned
Actual (not on schedule)
Actual (on schedule)
Holidays
ACTIVITY
Jan
Feb
Mar
Apr
W13
W14
W15
W16
W17
W18
W19
W20
W21
W22
W23
W24
W25
W26
W27
W12
Ongoing Evaluation of project and relationship to statement of intent
Evidence of project management, including a record of production
Design electronics mounting panel
Laser-cut prototype electronics mounting panel
Breakout PC Power Rails
Disassemble chassis to: test motors without wheels attached and prepare for fabrication
Test motor driver and motors
Modify wheelchair chassis according to working drawings (Welding and Steel Fabrication)
Install: Motors, Wheels and Batteries into Robot after chassis modification
Install Computer into Robot
Connect power cabling, screw terminals and fuses in Robot
Install Motor Driver PCB into Robot
Test motor rotation (Get Video Evidence)
Design user interface face plate in CAD
Laser-cut user interface face plate
Install IMU into Robot
Attach GPS Reciever to USB to TTL Serial Module
Install GPS Reciever Into Robot
Write software (Motor control, Joystick control, GPS and IMU drivers)
Configure/Calibrate software (Motor control, Joystick control, GPS and IMU drivers)
Design web interface for remote teleoperation
Design aluminium cover using CAD
Fabricate Aluminium cover
Order: cable glands, switches, screw terminals, power cabling, polarised connectors, fuse block
Order second computer, Kinect ToF camera, IMU, GPS Receiver, motor driver and touchscreen

Terms 2&3 2015



Finance Plan

Part Name	Qty	Source	Est. Price / Unit	Est. Total	Actual total	Reasons for differences
Second hand electric wheelchair chassis (including motors and wheels)	1	Ebay	$400	$400	$75	Purchased at a discounted price from a friend
Zippy Compact 5.8Ah 6S Lithium Polymer Battery	1	Hobbyking	$67.50	$68	$68	
Turnigy MAX80W Battery Charger	1	Hobbyking	$29	$29	$29	
1 inch square box section steel (1m Length)	1	Scrap Metal	$30	$30	$0	Recycled some scrap box section from my home workshop
A3 4.5mm Black Gloss Acrylic Sheets	2	Acrylics Online	$8.50	$17	$17	
300*600*4.5mm Red Gloss Acrylic Sheet	1	Acrylics Online	$7.50	$8	$22.50	
4GB DDR3 RAM Sticks	2	PC Case Gear	$100	$200	$0	Recycled from a previous robot I had built as a hobby project
128GB OCZ Vertex 4 SSD	1	PC Case Gear	$120	$120	$0	Recycled from a previous robot I had built as a hobby project
M3-ATX-HV DC-DC ATX Power Supply	1	mini-box	$70	$70	$0	Recycled from a previous robot I had built as a hobby project
M350 Mini-ITX enclosure	1	mini-box	$35	$35	$0	Recycled from a previous robot I had built as a hobby project
Gigabyte Mini-ITX Motherboard	1	PC Case Gear	$120	$120	$0	Recycled from a previous robot I had built as a hobby project
Intel i3 3220T CPU	1	PC Case Gear	$120	$120	$0	Recycled from a previous robot I had built as a hobby project
Parallax Ping Ultrasonic Sensors	5	Robotshop	$30	$150	$150	
Parallax Ping Brackets	5	Robotshop	$15	$75	$75	
18mm IP67 Cable Glands	4	Jaycar	$7.95	$32	$0	Salvaged/Recycled from old outdoor electronics enclosure
Sabertooth 2x25 dual 25A H-Bridge motor driver	1	Robotgear	$150	$150	$150	
Arduino Mega 2560	1	Little Bird Electronics	$60	$60	$60	
Robogaia 3 Axis LS7366R Based encoder shield	1	Robogaia Store	$43	$43	$43	
Deutsch DT Series Plug	5	TE Connectivity	$3.50	$18	$18	

Deutsch DT Series Receptacle	5	TE Connectivity	$3.50	$18	$18	
Wire inline Fuse Holders	1	Jaycar	$5	$5	$0	Sourced from my shed
Solid State Relay	1	Jaycar	$50	$50	$0	Recycled from a previous robot I had built as a hobby project
Kinect RGB/Depth Camera	1	Ebay	$80	$80	$80	
Avago HEDS-9100 Quadrature Rotary Encoder	2	Element14	$137	$274	$0	Salvaged/Recycled from some medical equipment waste
Toggle Switches	1	Jaycar	$13	$13	$13	
Large Red Emergency Stop Button	1	Jaycar	$10	$10	$10	
Pushbuttons	4	Jaycar	$5	$20	$20	
Altronics K5136 20W 12V Stereo Amplifier Kit	1	Altronics	$50	$50	$50	
Clarion SRG1022R Speakers	2	NewEgg	$55	$110	$110	
4 Pin 0.1” connectors	2	Little Bird Electronics	$0.20	$0.40	$0.40	
Solder	1	Jaycar	$10	$0	$0	Sourced Cable from my shed
Dual Core Power Cables 1m	2	Jaycar		$0	$0	Sourced cable from my shed
Heat shrink Kit	1	Jaycar	$15	$15	$0	Sourced heat shrink from kit in my shed
Plastic Cable Sleeving Kit		Jaycar	$15	$15	$0	Sourced some cable sleeving from my shed.
Aluminium Panel		Scrap Metal	$30	$30	$0	Salvaged as scrap, was an old sign
Two tone Paint/Painting		Car Paint Shop	$150	$150	$150	
Orthogonal Drawings of Wheelchair		Student Colleague	$35	$35	$35	
RoboPeak RP Lidar	1	DFRobot	$398	$398	$0	On loan from a friend
			TOTAL	**$3,152.00**	**$1,193.90**	

The projected cost for the project resulted much higher than I was expecting, but the cost of the project fell at only 38% under the predicted budget due to the fact that I actively recycled and/or sourced most of the materials/technologies from some of my other electronics projects that I had previously undertaken.

I also got some parts: at a discounted price or on loan from friends, at the Sydney Makerspace (Robots & Dinosaurs), which I regularly visit.

Record of production

20/12/2014

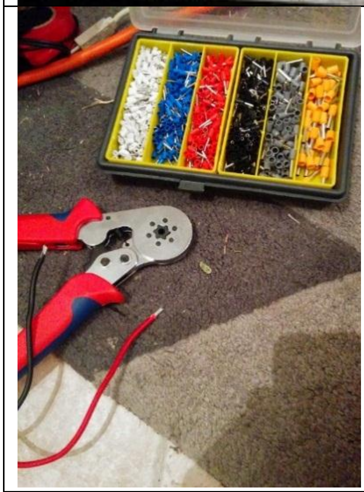
I Purchased the wheelchair chassis

Ongoing Evaluation

I purchased a used electric wheelchair base from a friend. This friend salvaged it from a hospital as medical waste, and had started repairing it. He offered it to me for about a quarter of the online used price, which I was expecting to pay. This brought the project ahead of schedule and under budget.

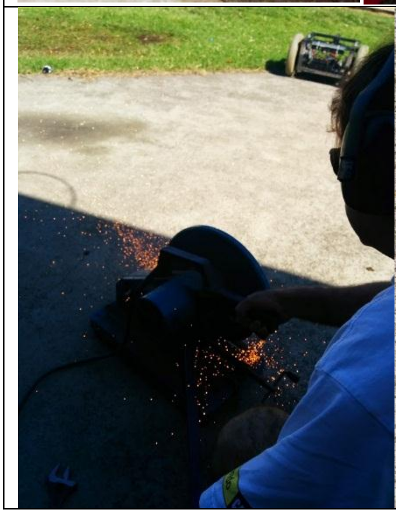
10/1/2015

I soldered wires onto the IMU allowing me to test and prototype with this sensor.



15/1/2015

I crimped boot lace ferrules onto the motor wires.



7/1/2015

I got a third-party to cut some steel box section according to my CAD working drawings allowing me to get it welded onto the robot chassis.

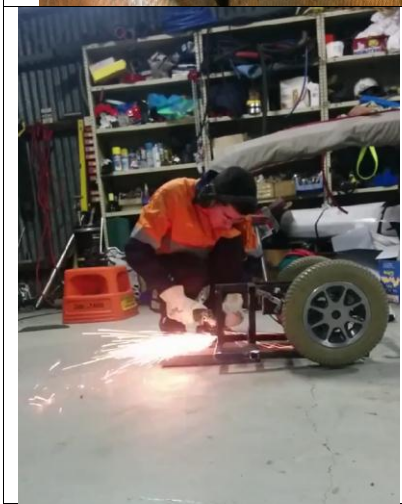
7/1/2015

I disassembled the wheelchair chassis ready for fabrication

21/1/1015

I got the rear of the chassis welded by a third-party according to my CAD working drawings.

On the left is what the chassis looked like prior to welding.

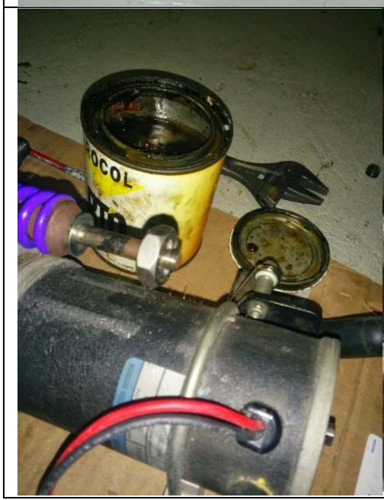


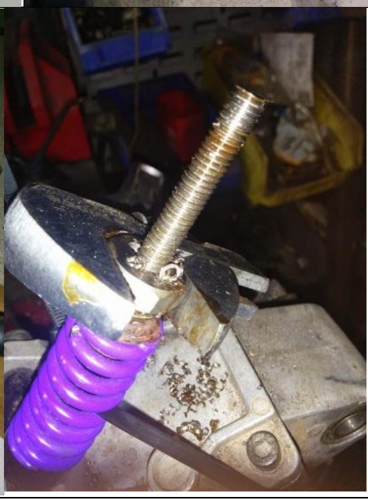
22/1/2015

I ground down the chassis using an angle grinder for a nice smooth finish.

The newly welded rear of the robot chassis can be seen on the right image and compared to the previous record of production entry.

Notice the use of PPE and safe working practices, see more detail under "Evidence of WHS and Safe Working Practices" Heading



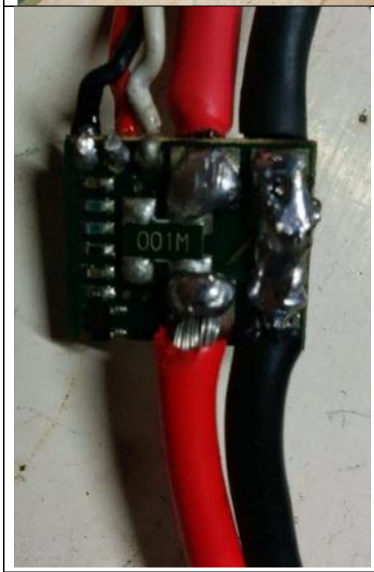


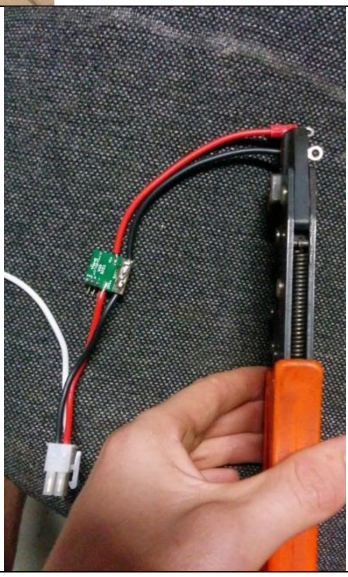
23/1/2015

I cut down the mounting bolts on the motors because they were extruding unnecessarily from the chassis, they required cutting of extra thread because there wasn't enough left.

23/1/2015

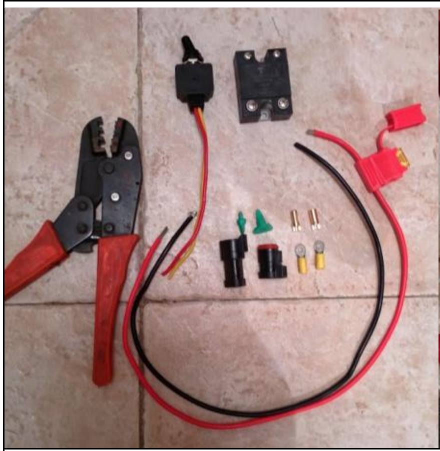
I drilled holes in the chassis allowing me to mount the laser cut face plate. And then reassembled the robot chassis.

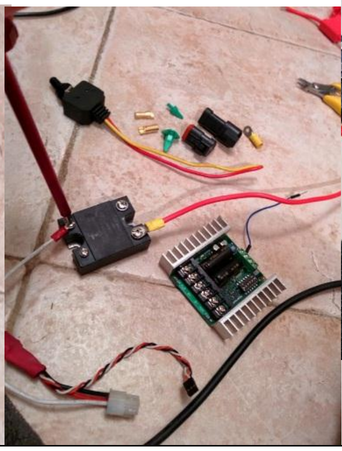




20/2/2015

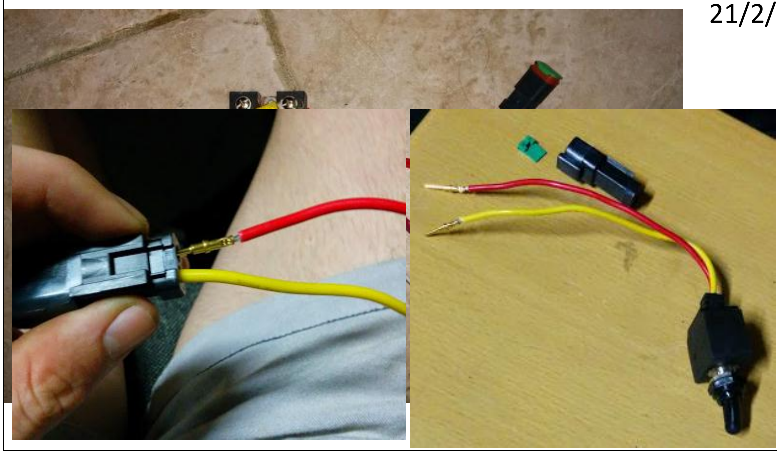
I soldered, crimped and heat shrunk the computer current sensor.





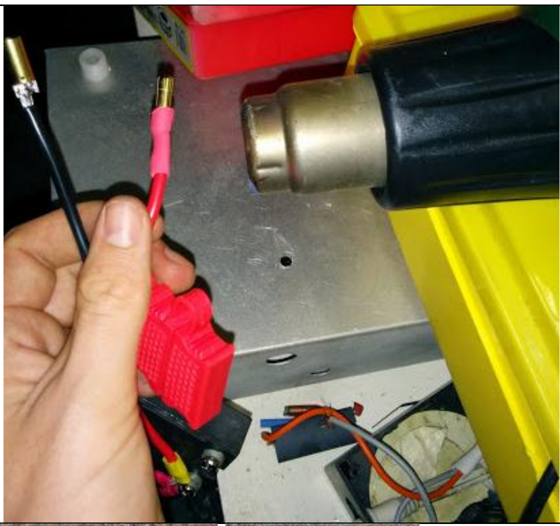
21/2/15

I proceeded to crimp the wiring between the battery, the motor driver and solid state relay, including the fuses



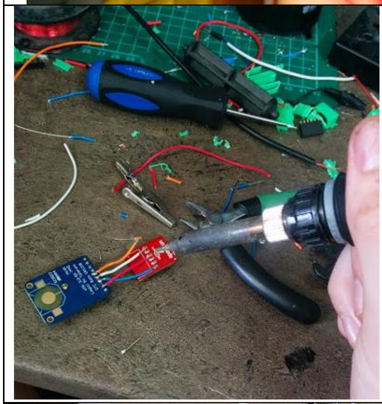
21/2/15

I then crimped the wiring between the solid state relay and the switch

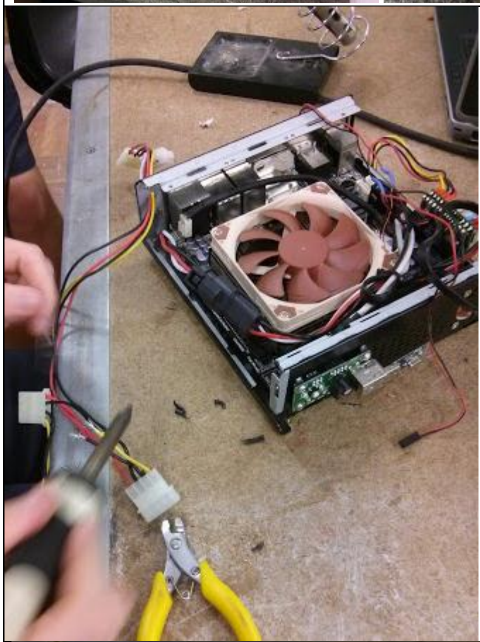
25/2/2015

I soldered on and heat shrunk the battery connectors



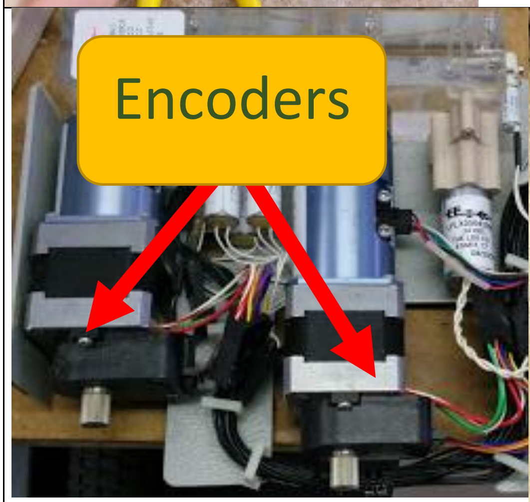
15/3/2015

I soldered the GPS reciever to the TTL serial to USB converter



20/3/2015

I broke out the 5V and 12V voltage rails from the computers ATX power supply so that these voltage rails are accessible for lower voltage auxiliary devices external to the computer. (The battery is 22.2V)



2/5/2015

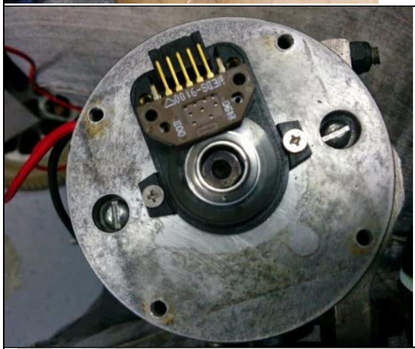
I **recycled** some quadrature encoders (shaft rotary position sensors) from some **electronic waste** from a medical facility.

I ensured they were thuroughly cleaned before removing and working with them.



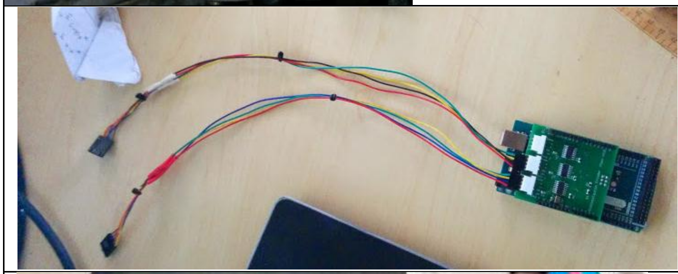
2/5/2015

I removed the end caps off both motors and proceeded to drill and tap out holes so the encoders could be mounted onto the rear shaft coming out of the motors.



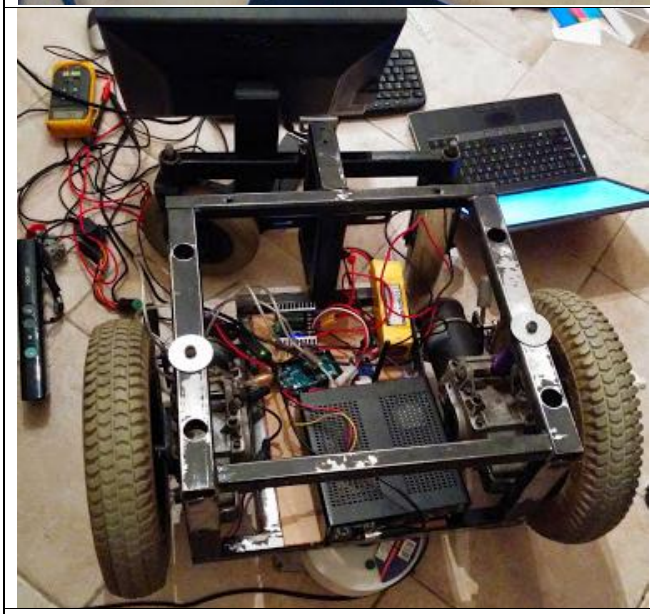
2/5/2015

I reinstalled the motor end caps and mounted an encoder to each the rear motor shafts using screws.



3/5/15

I soldered and heat shrunk the custom cables to attach the specific encoders to my quadrature decoder board.

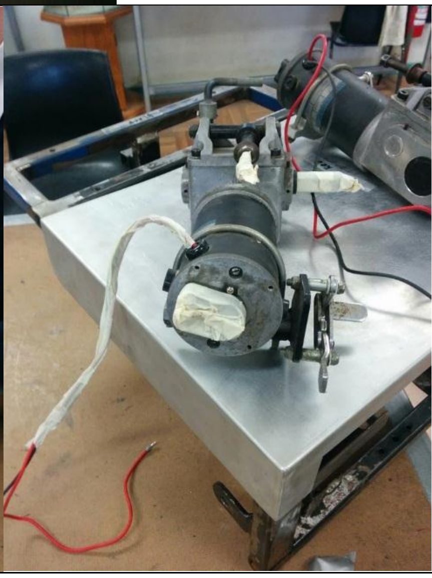


Once I had installed all the boards/modules, and troubleshooting the robot was in a working state, I had almost finished the production (apart from painting) and was ready for testing and programming.

At this stage I was testing and prototyping the electronics and the software for the robot. (For more information on what was being tested/implemened at this stage look under the: “Prototyping modelling and testing”, “Degree of dificulty” and “ICT Skills” headings).

13/6/15

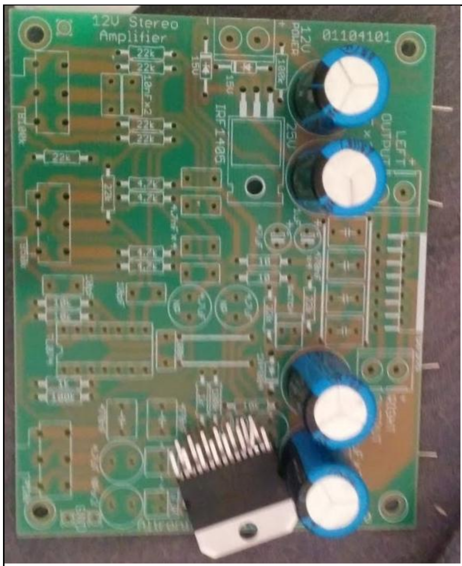
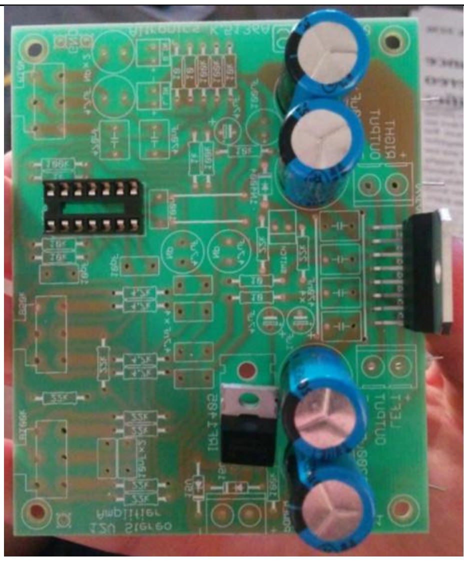
I laser cut the acrylic for the rear user interface panel. I first cut some panels out of cheaper wood material to prototype. I was still undecided a this stage on whether to use red or black.

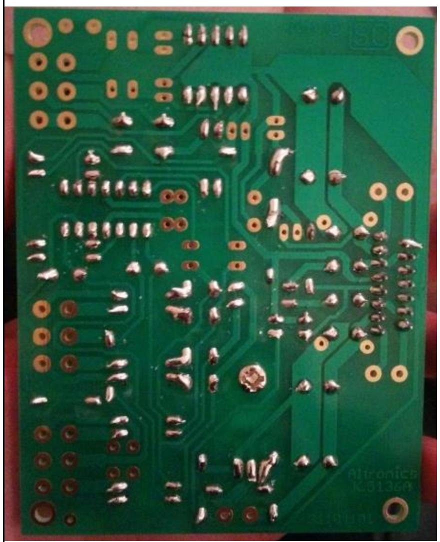
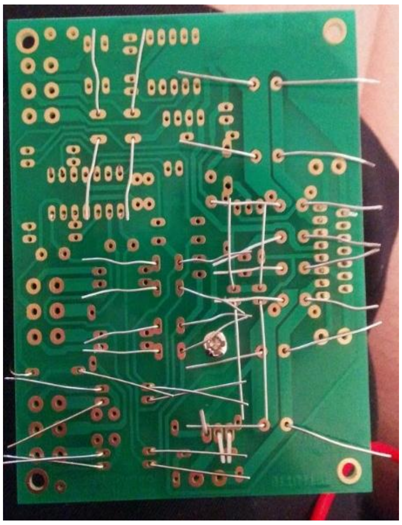


15/7/15

I fabricated some mounting brackets for the electronics panel out of an angular section of steel and had a third party weld them onto the chassis.

I then prepared the chassis for painting, by masking up parts that were not to be painted. I delivered the chassis, wheels and motors to a third party to have professionally painted.

20/7/15

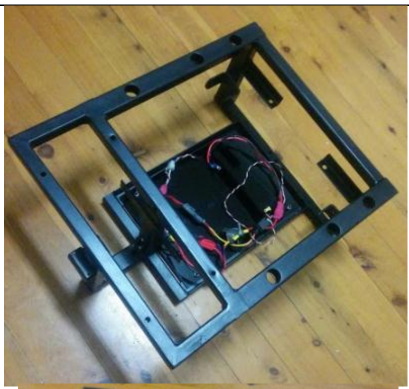
There was a **2 month delay** on the shipment on the audio amplifier because the store had run out of stock, I consulted the store numerous times via phone to check on the status of my order.

I proceeded to carefully assemble the audio amplifier, it took about 4 hours to carefully complete assembly.

Because of the long shipping delay and the minimal amount of time left for the project (17 days) I decided to only spend about 3 hours troubleshooting (see more information under “Evidence of soltuions to problems in production” heading) and leave it, because it is a **non-critical part of the project**, and I had to focus on finalising/editing/improving my folio at this stage.

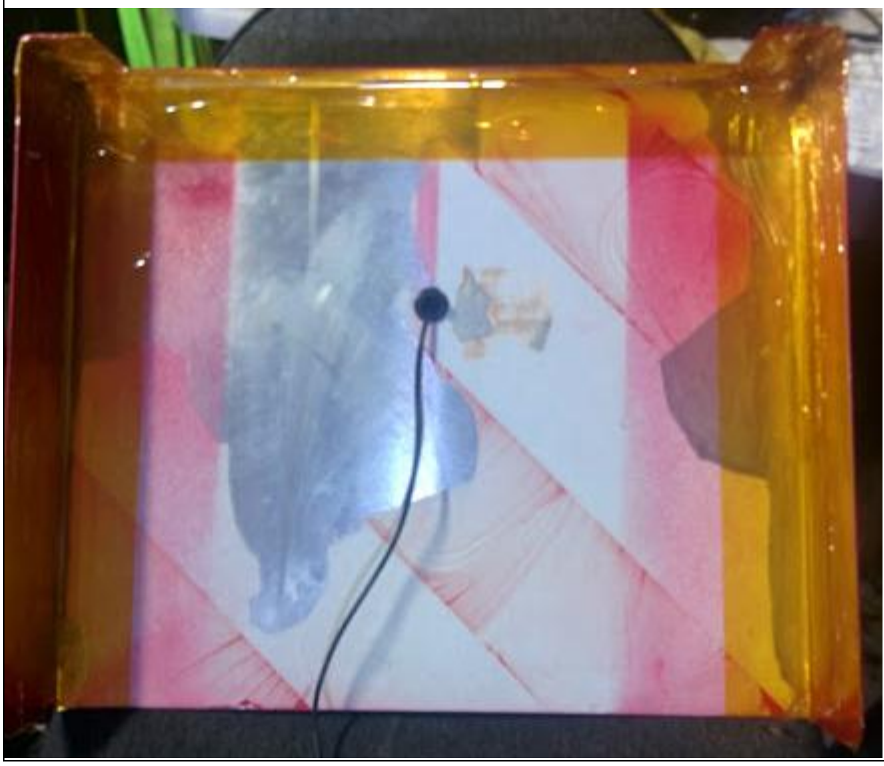
Ongoing Evaluation

Due to the long shipping delay which was **out of my control** and the minimal amount of time left for the project. I decided to only spend a day and leave it, it is a **non-critical part of the project, and I needed to focus on other tasks on the project.**



21/7/15

I received the parts back from painting, and was ready for the final assembly of the project.



I installed some non-abrassive tape around the edges underneath the enclosure lid, to ensure the black paint on the frame would not get scrached by the metal lid.

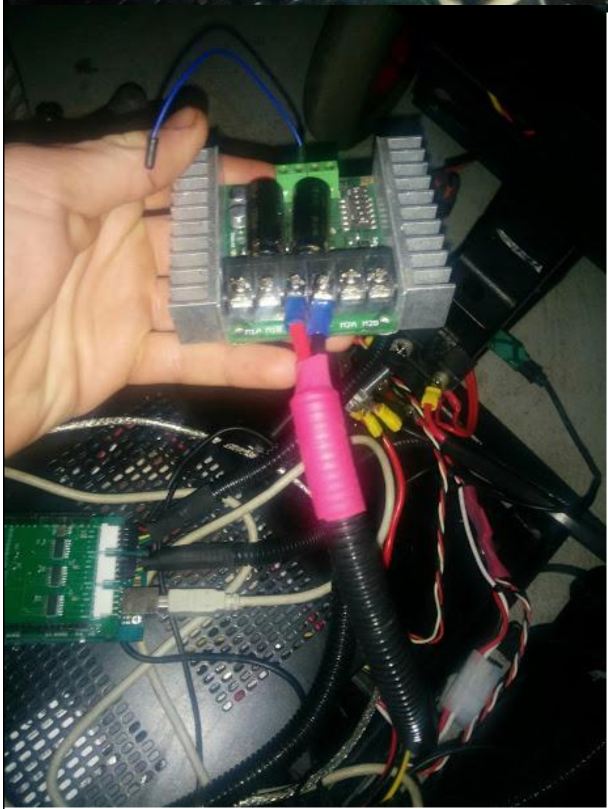

I then re-assembled the robot completely.

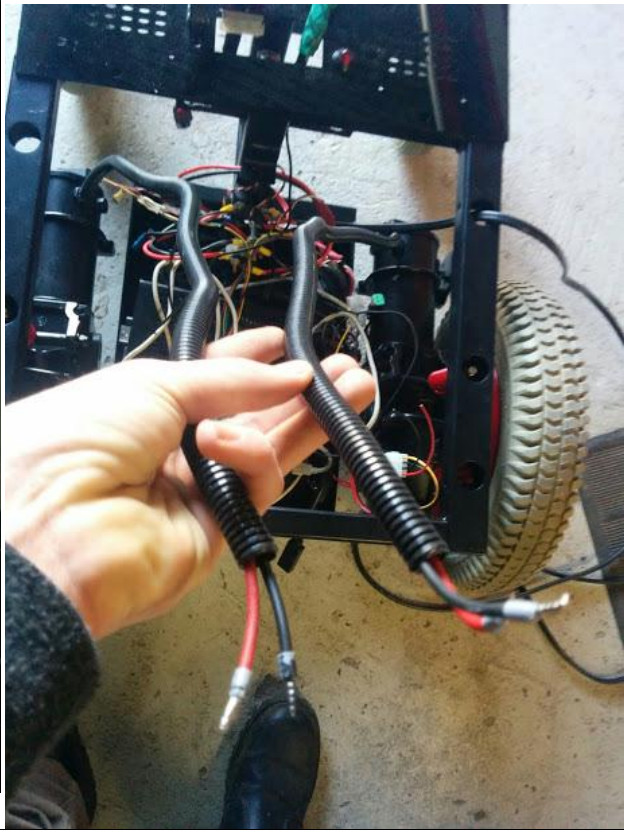

22/7/15

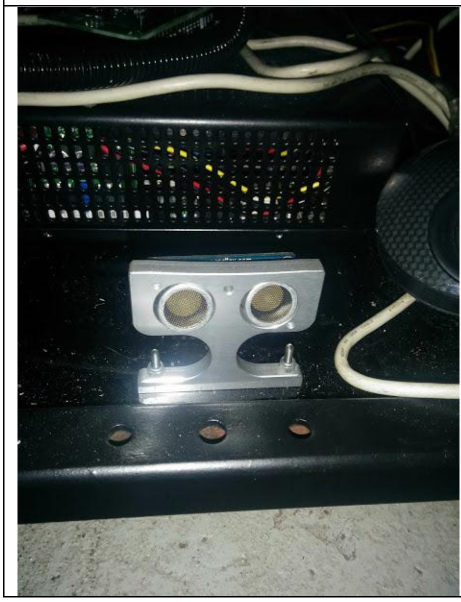
I Installed the 2D LIDAR sensor onto the top of the lid, so It has a clear view of the surrounding environment.

23/7/15

I Installed cable sleeving onto the motor wiring to protect them from damage, and also to improve the aesthetics.







24/7/15

I installed an ultrasonic sensor.

Evidence of WHS and Safe Working Practices

During the project, WHS was of uppermost concern. Here is a labled diagram of the PPE I wore while performing grinding. Followed by some images of me working while wearing the necessary PPE.

As evident in the above photographs, safe working practices were taken seriously while completing this project. I followed the Machine Safe operating Procedures and Safety Regulations.

Presentation skills and Techniques, including ICT Skills

Presentation skills and techniques

Practical

In the practical I undertook steps to ensure that the Robot looks presentable and aesthetically pleasing, these steps include:

- Using a consistent two tone red and black colour scheme throughout the Robot
- Using glossy laser cut panels for the control panel and to mount the internal electronics
- Ensuring all wiring throughout the project is routed in a tidy and logical fashion (all wires no longer or shorter than necessary, heat shrink on all joins, use of cable ties and cable glands)

Folio

I used various presentation techniques throughout the folio to ensure that it is easily readable, understandable and easy to navigate, these techniques include:

- A consistent colour and font scheme throughout the folio to make it presentable and easily understandable.
- Page numbers and a table of contents to ensure the folio can be easily navigated.
- Text boxes throughout the folio for the ongoing evaluation.
- Tables to present the: selection and justification of appropriate materials processes, technologies and resources, finance plan, written timeline plan.
- Colourful and readable graphs to present the results for the modelling and testing and Gantt chart.
- Large number of photographs to provide a record of production of the project.
- Diagrams and schematics in the research section.

ICT Skills

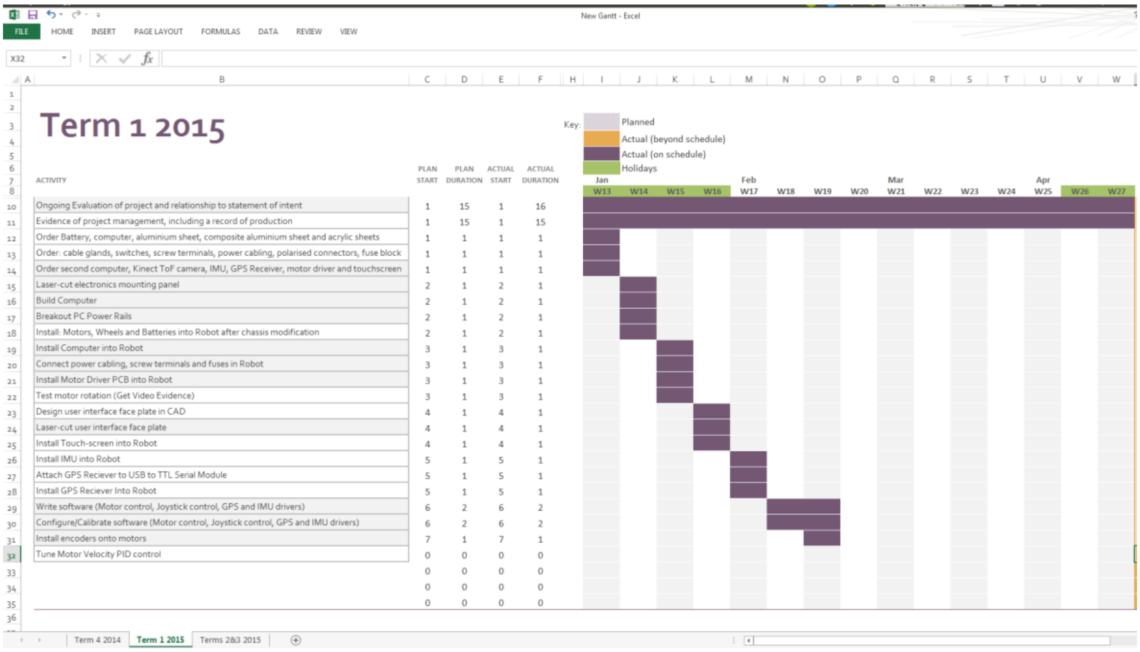
Office Programs

Microsoft Word

I used Microsoft word to produce the written folio for the project.

Microsoft Excel

I used Microsoft Excel to produce the Gantt chart and to automate the calculations for the finance plan.



Term 1 2015

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION
Ongoing Evaluation of project and relationship to statement of intent	1	15	1	16
Evidence of project management, including a record of production	1	15	1	15
Order Battery, computer, aluminium sheet, composite aluminium sheet and acrylic sheets	1	1	1	1
Order: cable glands, switches, screw terminals, power cabling, polarised connectors, fuse block	1	1	1	1
Order second computer, Kinect ToF camera, IMU, GPS Receiver, motor driver and touchscreen	1	1	1	1
Laser-cut electronics mounting panel	2	1	2	1
Build Computer	2	1	2	1
Breakout PC Power Rails	2	1	2	1
Install: Motors, Wheels and Batteries into Robot after chassis modification	2	1	2	1
Install Computer into Robot	3	1	3	1
Connect power cabling, screw terminals and fuses in Robot	3	1	3	1
Install Motor Driver PCB into Robot	3	1	3	1
Test motor rotation (Get Video Evidence)	3	1	3	1
Design user interface face plate in CAD	4	1	4	1
Laser-cut user interface face plate	4	1	4	1
Install Touch-screen into Robot	4	1	4	1
Install IMU into Robot	5	1	5	1
Attach GPS Reciever to USB to TTL Serial Module	5	1	5	1
Install GPS Reciever Into Robot	5	1	5	1
Write software (Motor control, Joystick control, GPS and IMU drivers)	6	2	6	2
Configure/Calibrate software (Motor control, Joystick control, GPS and IMU drivers)	6	2	6	2
Install encoders onto motors	7	1	7	1
Tune Motor Velocity PID control	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0

Software Development

I used a combination of my own software (see more info below) and some other pre-existing software to make the Robot function and navigate

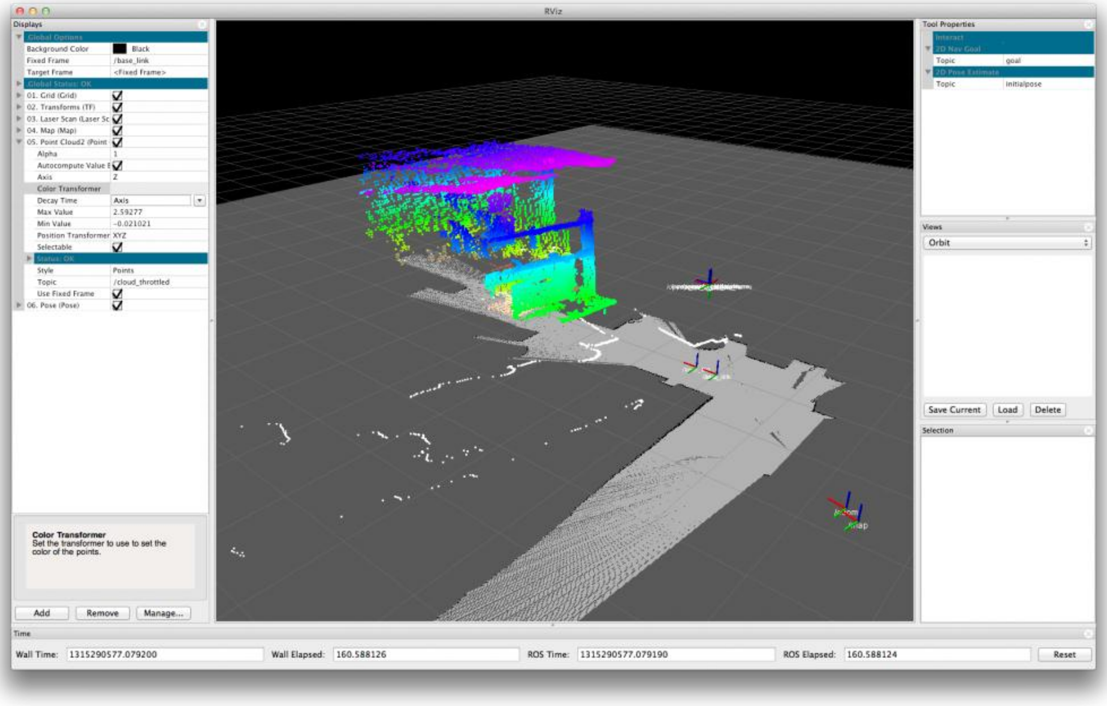
Robot Operating System (ROS) Framework

ROS is a (Linux based) framework designed specifically for writing Robot software. It provides tools and libraries for writing software for Robots and Autonomous Vehicles.

ROS.org

It includes:

- Various drivers for interfacing to sensors (e.g. cameras, GPS, IMU, LIDAR, wheel encoders) and also controllers like joysticks
- A communications framework allowing the sensors to communicate with the C++ and Python programs
- Tools and libraries to performing robot localisation and mapping
- Tools to visualise the robot and the what it perceives around it in 3D space

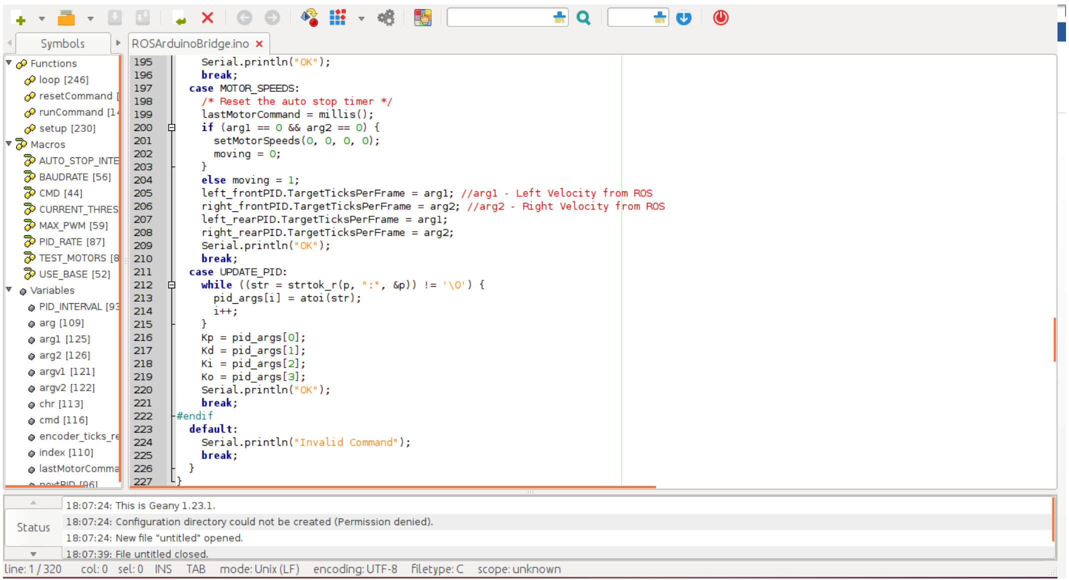


C Programming

I wrote various drivers to interface my specific: motor drivers, IMU, motor encoders, voltage and current sensors to ROS using a USB serial bridge.

The software I wrote (which is loosely based upon ROS Arduino Bridge) performs real time closed loop PID motion control for the motors providing a form of traction control similar to Electronics Stability Control on Cars (see more about PID Control in Degree of Difficulty Section).

I compiled this software using the AVR-GCC Compiler and loaded the Compiled Hex file onto the Atmega 2560 Microcontroller using RX-TX Serial

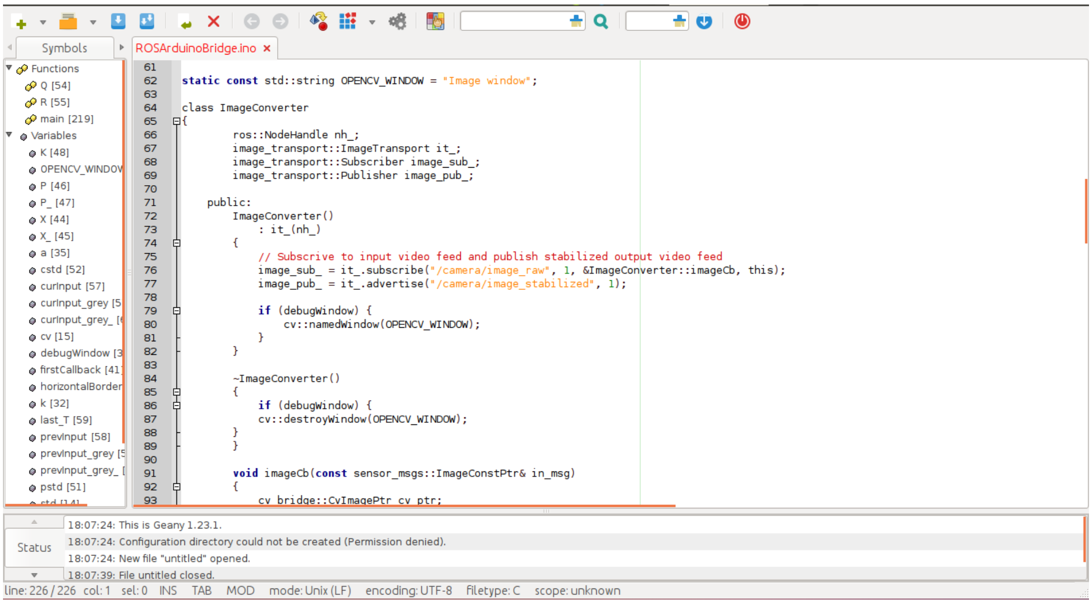


C++ Programming

I wrote a ROS wrapper for an image stabilisation program using the C++ programming language

This program stabilizes the live video stream coming from the on-board robot camera which is blurry due to the fast and abrupt motion of the robot.

The software I wrote software uses feature detection and optical flow on the image stream using the OpenCV Computer Vision library, it detects the transformation between consecutive frames and stabilises the image using a Kalman Filter.



Python Programming

I wrote a program using the Python programming language that sets a robot navigation goal for the robot in ROS when provided with a path from an array of GPS coordinates

Symbols | ROSArduinoBridge.ino

- Variables
  - WPUpdateState [
  - asin [11]
  - cos [11]
  - currPosX [74]
  - debug [19]
  - desiredPose [95]
  - lastValidFixTime [
  - latCur [39]
  - latCur [44]
  - lonCur [39]
  - lonCur [44]
  - lonWP [39]
  - lonWP [44]
  - pi [11]
  - pow [11]
  - radians [11]
  - robot [94]
  - sin [11]
  - sqrt [11]

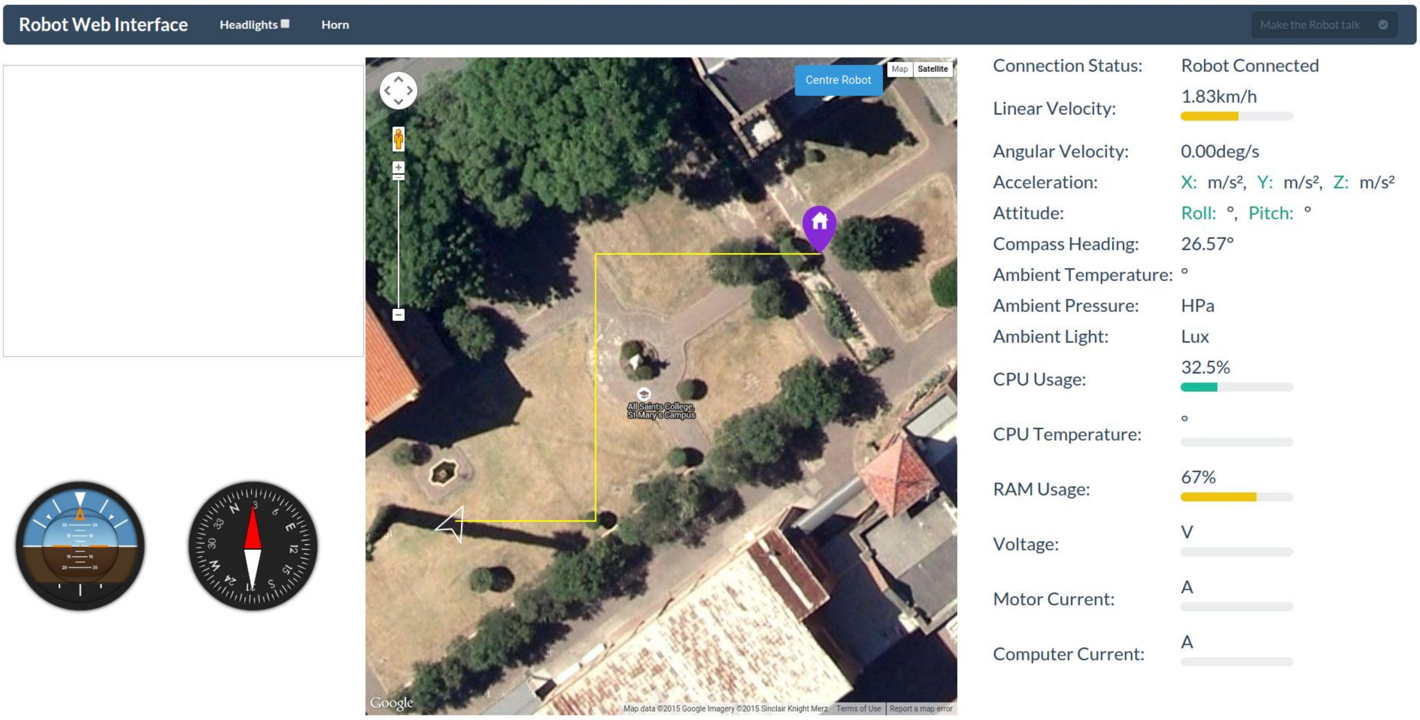
```python

def haversineDistance(latCur, lonCur, latWP, lonWP): #Returns distance to waypoint in Metres
    latWP, lonWP, latCur, lonCur = map(radians, [latWP, lonWP, latCur, lonCur]) #Convert into Radians to perform math
    a = pow(sin((latWP - latCur)/2),2) + cos(latCur) * cos(latWP) * pow(sin((lonWP - lonCur)/2),2)
    return earthRadius * 2.0 * asin(sqrt(a))  #Return calculated distance to waypoint in Metres

def bearing(latCur, lonCur, latWP, lonWP): #Bearing to waypoint (degrees)
    latWP, lonWP, latCur, lonCur = map(radians, [latWP, lonWP, latCur, lonCur]) #Convert into Radians to perform math
    dLon = lonWP - lonCur
    return atan2(sin(dLon) * cos(latWP), cos(latCur) * sin(latWP) - (sin(latCur) * cos(latWP) * cos(dLon)))

def gpsSubscriber(gpsMsg): #GPS Coordinate recieved from ROS topic, run this function
    if gpsMsg.status.status > -1: #If there is a GPS fix (Either Augmented or Unaugmented)
        global latCur
        global lonCur
        global lastValidFixTime

        lastValidFixTime = rospy.get_time()
        latCur = gpsMsg.latitude
        lonCur = gpsMsg.longitude
        if debug == True:
            rospy.loginfo("GPS Fix Available, Latitude: %f, Longitude: %f", latCur, lonCur)

def gpsFixIsValid(): #Check to see if there has been a GPS fix within the last <gpsValidityTimeout> seconds
        global gpsValidityTimeout

        if (rospy.get_time()- lastValidFixTime) < gpsValidityTimeout:
            return True
        else:
            rospy.loginfo("GPS Fix Invalid! Last valid update was: %f seconds ago", rospy.get_time()- lastValidFixTime)
            return False

def robotPoseSubscriber(poseMsg): #Odometry update recieved from ROS topic, run this function
    global currPosX
    global currPosY
    global currPosZ

    currPosX = poseMsg.pose.pose.position.x
```

line: 137 / 137 col: 12 sel: 0 INS TAB MOD mode: Unix (LF) encoding: UTF-8 filetype: C scope: unknown

Web Development (JavaScript, CSS and HTML programming)

To control and monitor the robot, I developed a comprehensive web interface (website) by myself using: HTML, JavaScript and CSS.

Below is a demo of the web interface displaying the path of the robot after driving it around the schoolyard. (Note: several sensors were not installed at the time of this demo; hence the web interface is not displaying the data from them)



The web interface allows a remote operator to:

- View the robots live GPS position and path on a map
- View the (stabilised) video image stream coming from the robots RGB camera
- View readings from the on-board sensors, including:
  - Battery voltage
  - Computer CPU and RAM usage
  - Computer Current
  - Computer temperature
  - Ambient temperature and barometric air pressure
  - Motor current
  - Motor speed
  - Magnetic Compass heading
  - Acceleration
  - Orientation
- Make the robot talk by entering some text
- Control the headlights and horn

The web interface runs off the robot itself and can be accessed from a: computer, phone or tablet located on: the same wireless network as the robot, or the internet using a Virtual Private Network (VPN).

GitHub Version Control

I used GitHub version control to manage all the: design files, software I produced and the folio, Git synchronises these files online.

I did this to ensure:

- I always had an online backup copy of my work
- That I was always editing the latest version of these files no matter what computer I was using to do so

If there was a save overwrite conflict of two different versions of a file I could easily merge the changes from both versions together without losing any data/work.

This successfully prevented me from accidently losing any digital work from this project.

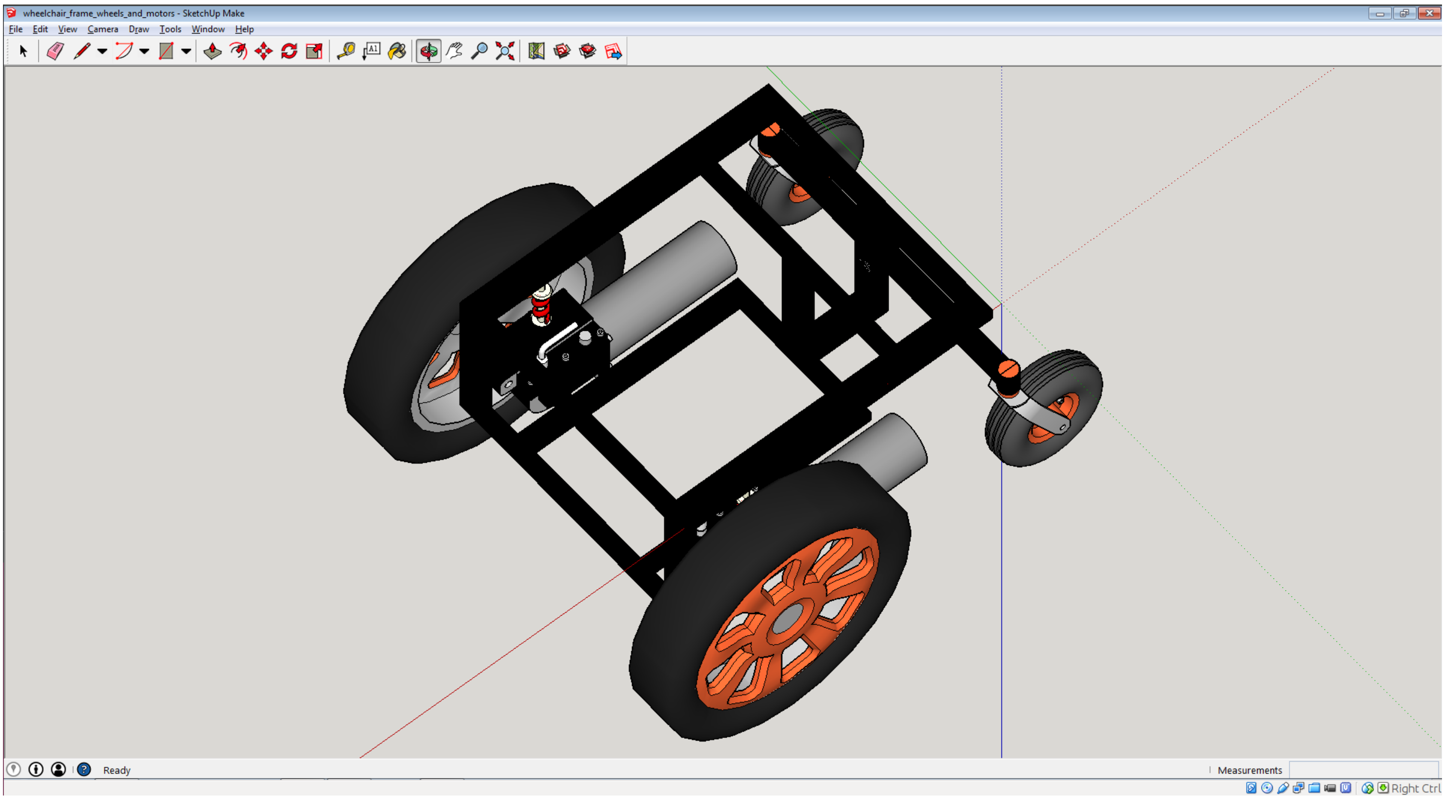
Diagram Production

For the block diagram of the project I used Gliffy online diagram editor, for the Gantt Chart I modified a template on Microsoft Excel and for the graphs displaying sensor readings from the robot I used Python MatPlotLib.

CAD

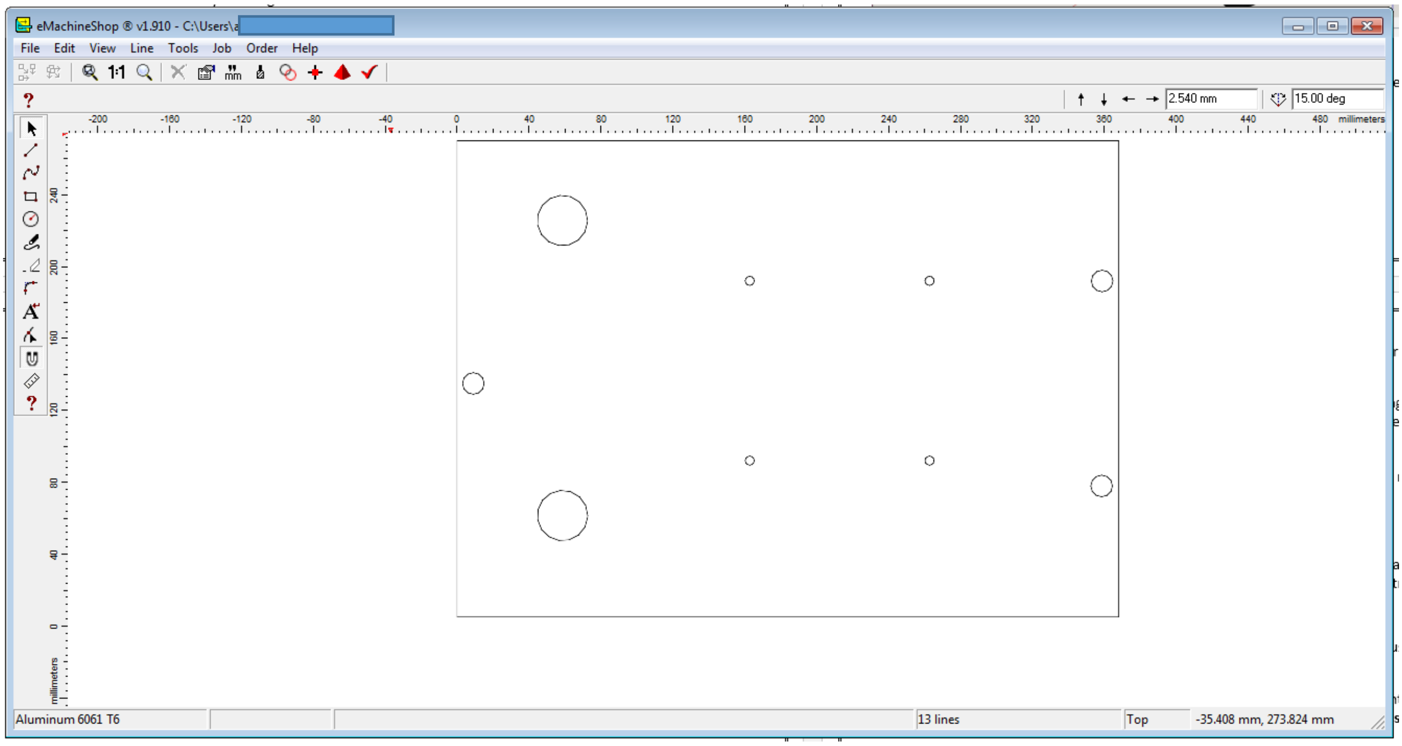
Trimble Sketchup

I used Trimble Sketchup (previously known as Google Sketchup) to produce the 3D CAD working drawings for this project.



eMachineShop

I used eMachineShop 2D CAD software to produce the 2D designs for the Laser Cutter.



Ongoing Evaluation of the project and relationship to the statement of intent, research and planning

The ongoing evaluation can be seen throughout the folio in the green textboxes.

I also included a monthly evaluation of the project below.

October

During October, after submitting my first planning task which included the:

- Statement of intent
- Research
- Selection and justification of materials, processes and resources
- Sketching and Idea Generation
- Finance plan
- Timeline plan

My plan for the major work was approved my class teacher. I then proceeded to order some of the parts for the robot that I selected in the Selection and justification of materials, processes and resources.

I produced some working drawings while the parts were in shipment and hence I was unable to partake in any production work.

At this early stage everything was running smoothly and on schedule.

November

During early November I was still unable to engage in any production work because very few parts had arrived. I continued to work on the folio and also began writing software required for the project to be functional, including the motor and PID feedback control software.

I started to feel as if I was slipping behind schedule as I had limited prototyping production work completed.

At the end of November several large shipments of electronic parts arrived allowing me to start prototyping, modelling and testing parts, mainly the sensors. Everything seemed to work as expected with no problems as yet.

I was now back on schedule according to the timeline plan.

December

During Early December I continued with the prototyping, modelling and testing.

I decided to use a prebuilt chassis myself rather than fabricate one from scratch (full reasoning for this decision located under "Appropriate design and/or design modification" heading), so I began searching for a used wheelchair (or similar) chassis to use as the base for the robot.

On the 20th of December, I purchased a used electric wheelchair base from a friend. This friend salvaged it from a hospital, and had started repairing it. He offered it to me for about a quarter of the online used price; of which I was expecting to pay.

Towards the end of December I was unable to partake in much production work because I was away on holidays, but continued to write the software required to make the robot function

January

In early January I could now finish producing the 3D CAD working drawings based on the design of the chassis.

I now had to change my timeline plan to suit the production work that needed to be completed on the wheelchair chassis.

I disassembled the wheelchair chassis entirely.

I arranged to have the steel wheelchair chassis cut and welded by a third-party according to my CAD designs, once complete, I could now grind and sand down the chassis for a smooth finish.

While the motors were removed from the Chassis I was able to safely test them using my motor drivers. It took a week to successfully have the motors functioning with ROS and have adjustable speed control.

February

February consisted of setting up most of the electronics and installing them into the robot.

I was working very efficiently at this stage of the project and ahead of schedule.

March

During March I reassembled the robot, installing all the sensors I had available. I measured out the mounting holes of the parts and laser cut a prototype panel out of ply wood to mount all of the electronics.

I then began configuring the software on the robot, including joystick control.

I successfully drove the working partially completed robot around for the first time using a Joystick, this was a major milestone in the project.

This functionality was all that I set out to do as a <u>base level</u> in the statement of intent, I am now beyond schedule <u>allowing me to add the extra functionality that I listed in the statement of intent as “only if time permissible”.</u>

At the end of March I began developing the web interface for the robot and configuring the sensors.

April

In April I had the Aluminium top cover fabricated (bent and welded) from an old recycled sign.

I continued to configure the sensors on the robot and also continued developing the software required to make the project function.

I also I focused on developing the folio for the upcoming task 3.

May

In May, I salvaged and recycled some shaft encoders from some medical equipment waste and installed them onto the rear shaft on the motors.

I focused on completing the folio for the upcoming task 3 submission.

June

In June I configured the encoders and prototyped with other various sensors, including the 2D LIDAR, I attempted to configure the autonomous mapping and navigation software.

July

There was a 2 month delay on the shipment on the audio amplifier because the store had run out of stock, I consulted the store numerous times via phone to check on the status of my order.

I proceeded to carefully assemble the audio amplifier, it took about 4 hours to carefully complete assembly.

Because of the long shipping delay which was out of my control and the minimal amount of time left for the project (17 days) I decided to only spend a day troubleshooting (see more information under "Evidence of solutions to problems in production" heading) and leave it, it is a **non-critical part of the project, and I had to focus on other tasks on the project.**

I continued to finalise and edit my folio. I completed the final fabrication ready for painting on the 16th of July. I received the painted robot back on the 27th of July.

August

I finished the project on time, to the base level of being "teleoperated by an operator through a controller" as stated in the statement of intent.

I was unable to configure autonomous navigation functionallity before submitting the project, due to the degree of difficulty and time contstraints set, so unfortunately the robot will be unable to navigate a map autonomously **at the time of the submission** of the project, although I do plan to later get this funtionallity working.

Before submission I am detailing the project, ensuring that everything was **tidy** and up to a **high standard**, as I promised in the statement of intent.

PRODUCTION

HSC Industrial Technology - Electronics

BOS ID: 27051731

Quality of the Product

Wiring Quality

When building this project, I ensured that the wiring quality was of an extremely high standard and tidy, as I said I would in the statement of intent.

Some of the steps I took include:

- Ensuring all wires were no longer or shorter than necessary
- Using heat shrink on all wiring joins
- Routing all cabling efficiently and fastening using cable ties and glands
- Using wire sleeving to tidy and protect the wiring
- All wiring was modular, separated by convenient connectors making it easy to maintain

Finish Quality

As I stated I would in the statement of intent, I would complete project at I high standard. This included the finish of the robot.

I decided to get the robot professionally painted with a matte black and red two tone finish to yield appealing aesthetics.

I laser cut the fascia for the control panel out of glossy red acrylic (later I redesigned panel and cut in black acrylic) ensuring a professional finish, with an intent to make the robot easier to operate.

I also ensured that the surface finish was of an extremely high standard by grinding down the welds, and sand blasting metal the chassis and wheels.

Design Practicality

As I stated I would in the statement of intent, I ensured practicality of the robot was considered while designing it, I attempted to provide some ingress protection from the outdoor environment so that the electronics on-board could not be easily damaged by wet grass or light rain for example. I mounted the critical and electronics higher on the robot. All of the motor wiring and battery wiring located at the bottom of the robot uses waterproof connectors.

Another consideration taken into account was thermal design; I had to ensure airflow was available to the higher power electronics which dissipate a large amount of heat. I decided to use exhaust fans (inside the computer) for active cooling to increase the air flow over the electronics resulting in lower temperatures and higher efficiency.

Modularity and Expandability

When designing the Robot I ensured it was modular, as I set out to do in my statement of intent, for maintenance or upgrade purposes. I added convenient connector's on all of the wiring separating different modules of the robot allowing these modules to easily be individually: removed, repaired and/or replaced if necessary.

The robot can easily be converted to carry or move objects or people, by fabricating external attachments.

Quality of the folio

I used various presentation techniques throughout the folio to ensure is presented at a high quality. For example I used:

- A consistent colour and font scheme throughout the folio to make it presentable and easily understandable.
- Page numbers and a table of contents to ensure the folio can be easily navigated.
- Text boxes throughout the folio for the ongoing evaluation.
- Tables to present the: selection and justification of appropriate materials processes, technologies and resources, finance plan, written timeline plan.
- Colourful and readable graphs to present the modelling and testing and Gantt chart.
- A large number of photographs to provide a record of production of the project.
- Diagrams and schematics in the research section.

Range Of Skills

A wide variety of skills were required in this project including:

Project Management

Time and finance management skills, organisational skills, documentation skills and strong motivation were all requirements of this project.

This also includes organisation with third-parties by phone or face-to-face consultation to outsource certain tasks that:

- Require skills that I am untrained with; which could result in a low quality product or pose safety concerns.
- I lack sufficient tools/machinery to perform the task at a high quality level

For example: steel welding, metal painting with an air gun and sheet aluminium fabrication (bending and welding).

Soldering skills

Soldering skills are required to assemble the audio amplifier board and to interface to some sensor boards including the GPS receiver and the IMU and also to permanently join wires where necessary.

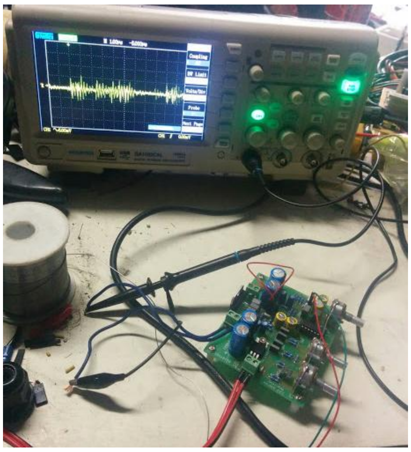
Mechanical production skills

For the mechanical production of the project I was trained how to safely operate an angle grinder and a band saw. This enabled me to grind and cut the chassis and some of the panels.

I also used a handheld electric drill to drill holes for mounting panels onto the chassis.

Troubleshooting skills

In order to have a functional robot, strong Electronics and Software troubleshooting skills were required. (See more info on the depth of troubleshooting under the "Evidence of solutions to problems in production" heading)



ICT Skills

I used a wide variety of ICT skills throughout this project. Software development skills were required to program and configure the robot in order for it to function. Computer Aided Design skills were required to design the Working Drawings

See further information on ICT Skills under the "ICT Skills" heading

Degree of Difficulty

Electronics

Motor Control

Configuring the motors was difficult because there was a lot of troubleshooting involved in order to get the motor controller to communicate with the microcontroller and then also the motor controller to communicate with ROS. I discovered that I had to use a microcontroller with more than one hardware UART port to get the motors working successfully.

Sensors

The sensors on-board the robot including the (GPS receiver, IMU, Barometer, Wheel encoders and Ultrasonic Proximity Sensors) use digital interfaces including I2C, SPI, PWM, Quadrature Square waves and UART to communicate to the microcontroller.

Configuring the sensors to work with the robot was difficult because I had to test and troubleshoot these digital signals using a combination of a digital oscilloscope and logic analyser.

Software development

Web interface

I developed an easy to use web interface (using HTML, JavaScript and CSS programming) so that the robot can be monitored and controlled the Robot from a remote computer, phone or tablet. This adds to the degree of difficulty of the project because of the programming and time management skills required to develop the software.

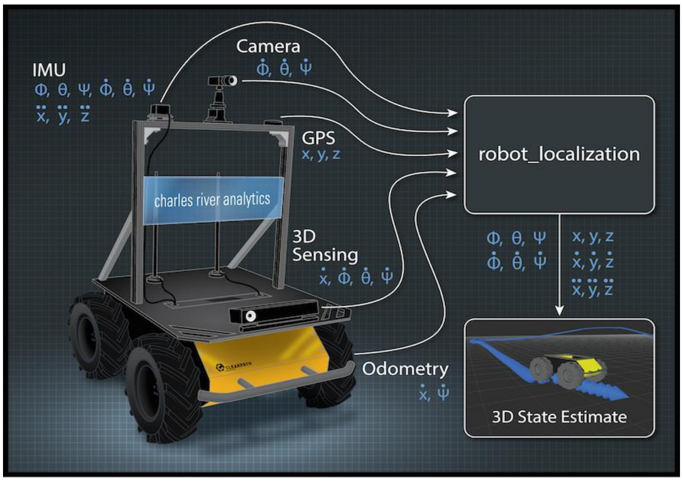
See further information about the degree of difficulty of the web interface under the “ICT Skills” heading.

Ongoing Evaluation

I successfully completed the physical production of the project on schedule, this allowed me to attempt to add extra robot functionality such as autonomous navigation or the web interface by writing software. I planned this extra functionality in the statement of intent, as “only to be done if time permissible”

Autonomous navigation, localisation and mapping

Sensor Fusion (Kalman Filter)



In order for the robot to estimate where it is, data from several sensors (Including: wheel encoders, IMU, GPS, camera) have to be combined, I configured a Kalman filter algorithm that is included with ROS, which dynamically determines the reliability of each of the sensor updates, and then determines how much weighting to give each sensor in order to reliably estimate the position of the robot.

It was extremely difficult and time consuming to configure the localisation algorithm to suit my specific robot because of the multitude of parameters and settings, having a working localisation algorithm is critical to having the robot to navigate autonomously.

Simultaneous Localisation and mapping

I configured a SLAM algorithm included with ROS in an attempt to make the robot navigate autonomously (See more information on SLAM and ROS under “Research” heading), it was very difficult to configure because of issues with calibration of my sensors in software.

I generated a map of a room, but it was skewed due to the sensors not calibrating properly, I did not have time to calibrate this before submitting the project, so unfortunately the robot will be unable to navigate a map autonomously **at the time of the submission** of the project due to the difficulty and time required to calibrate the sensors.

PID Control

I used a PID controller as a form of traction control (See more information on PID control under “Research” heading), ensuring that the wheels would not slip or get stuck, by measuring the speed using wheel encoders and compensating.

This was difficult to configure because by adjusting the PID tuning parameters incorrectly, and having discovered the encoders were reading backwards, the motors would start oscillate very violently.

It took about 3 hours of adjusting the PID parameters to a safe level, giving me precise control of each wheels velocity wheels.

Use of Appropriate Materials, Components, Processes and Technologies

Materials

The wheelchair chassis was made of steel which is a strong material that is very easy to fabricate compared to other metals.

The lid to enclose the electronics is made of Aluminium which is a lightweight metal but is still fairly strong.

The panels are made of glossy coloured acrylic which are very easy to laser cut.

Components

All the electronic/electrical components were chosen appropriately; well within their voltage and current rating limits to ensure that they will not get damaged with use.

I also ensured all of the electronics were modular and attached using convenient connectors so that the modules can be easily removed, upgraded or maintained if necessary.

Processes

All the processes used to produce the project were chosen appropriately, ensuring the highest possible standard of work, while also being time and cost efficient.

Technologies

Some of the processes used in the production were heavily reliant on technology; such as laser cutting or MIG welding.

The robot itself is heavily reliant on technologies, there are two computers, four microcontrollers and over 30 sensors on-board the robot enabling it to determine where it is and what is around it.

Links between planning and production

Relationship of production to statement of intent

In the statement of intent, I stated that I intend to build a “modular outdoor robot platform” that “as a base level” is to be “teleoperated by an operator through a controller”.

In March 2015, I successfully achieved this goal and have started configuring autonomous navigation, which I announced in my statement of intent “I may consider only if time permissible”.

Relationship of production to: “research of components, processes, technologies and resources” and “selection and justification of appropriate materials, processes and resources”

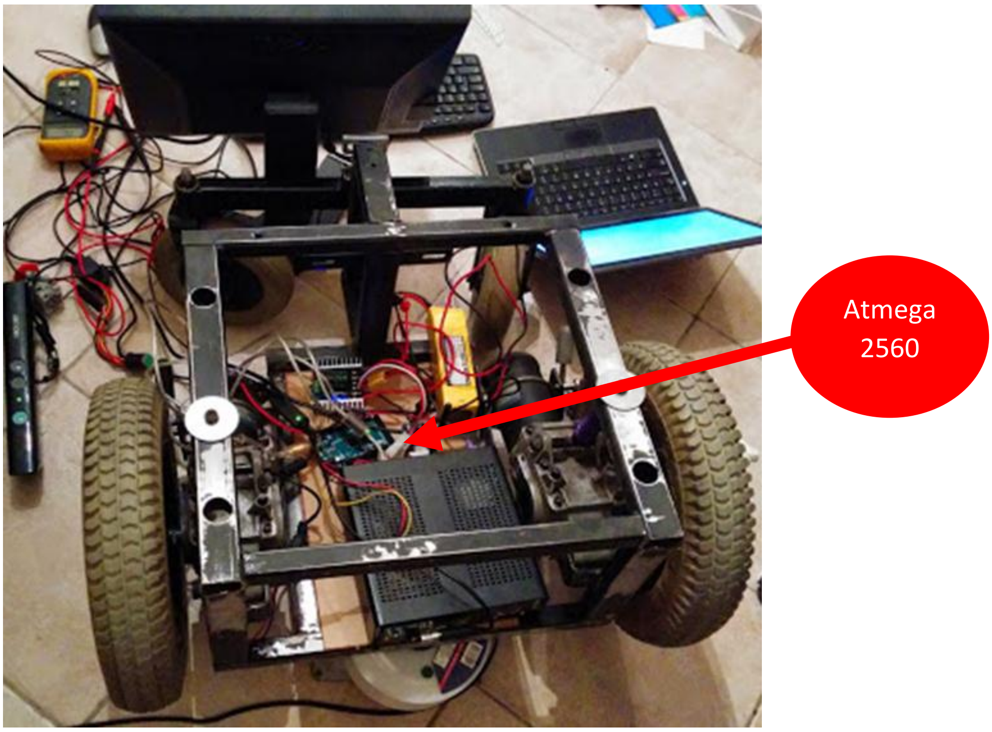
In the production of the project I used the majority of the parts that I selected under the “selection and justification of appropriate materials, processes” heading, which was based on my “research of components, processes, technologies and resources”.

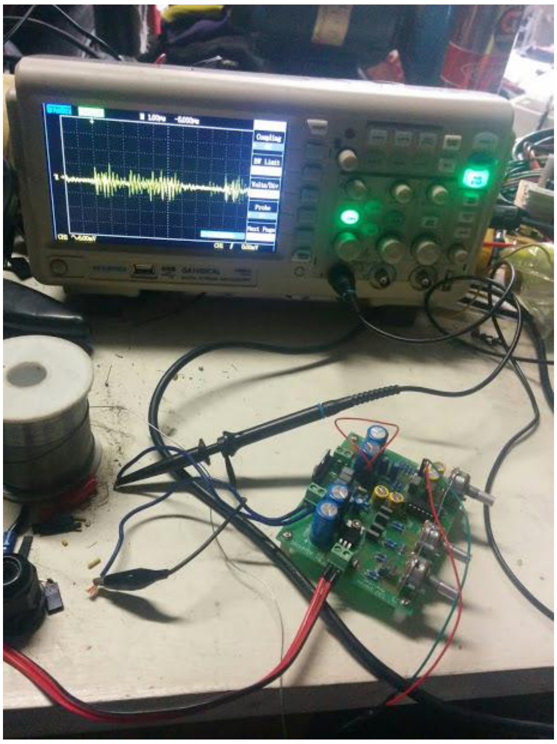
Any changes were noted under the “appropriate design and/or design modification” heading.

Evidence of solutions to problems in production

During the project I came across serial communication errors between the computer, the microcontroller and the motor controller because I was attempting to simultaneously use the hardware UART serial port and emulate software UART serial.

After troubleshooting the problem for several hours, I discovered that the software serial emulation was interfering with the hardware serial port, I was required to completely replace the Atmega328 microcontroller with an Atmega2560 microcontroller which features two hardware UART serial ports, and this fixed the problem.





Another Issue I faced in the project was with the audio amplifier not working, Because of the long **shipping delay** and the minimal amount of time left for the project (17 days) I decided to only spend about 3 hours troubleshooting using my digital oscilloscope.

The board was receiving power and an audio signal, but would not amplify this signal, I could not find any issues with the board under visual ispection nor was any components heating up.

I tried adjusing the amplification gains and testing each channel individually, but I was unable to get it to work.

There was only minimal amount of time left until the project was due, I decided to leave it in a non-working state, because it is a **non-critical part of the project**, and I had to focus on finalising the rest of the project and the folio at this stage.